Bulletin 199

March, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Varietal Experiments and First Generation Crosses in Corn

BY

R. J. GARBER, T. E. ODLAND,
K. S. QUISENBERRY, and T. C. McILVAINE

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------ President of the University
GEORGE R. LYMAN, Ph. D. ------------ Dean of the College of Agriculture
HENRY G. KNIGHT, Ph. D. ------------ Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr. ------------------- Agricultural Editor
JOHN C. JOHNSTON -- Chief Clerk

AGRONOMY

R. J. Garber, Ph. D.
Agronomist
T. E. Odland, M. S.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
M. M. Hoover, M. S.
Junior Agronomist
H. K. Rowley, B. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
E. C. Stillwell, M. S.
Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

Henry G. Knight, Ph. D. Chemist
R. B. Dustman, Ph. D.
Assistant Chemist
Chas. E. Weakley, Jr., B. A.
Assistant Chemist
T. B. Leith, B. A.**
Assistant Chemist
T. J. Cochran, B. S.
Junior Chemist

DAIRY HUSBANDRY

Ernest L. Anthony, M. S. Agr.
Dairy Husbandman
H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman
Warren Gifford, B. S. Agr.††
Junior Dairy Husbandman
G. M. Trout, M. S.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D. Entomologist
W. E. Rumsey, B. S.**
State Entomologist

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
Paul A. Eke, Ph. D.
Junior Farm Economist
F. D. Cornell, M. S.
Junior Farm Mechanician
W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D.
Home Economist

HORTICULTURE

M. J. Dorsey, Ph. D.***
Horticulturist
H. L. Crane, M. S. Agr.
Associate Horticulturist
H. E. Knowlton, Ph. D.
Associate Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
Ernest Angelo, M. S. Agr.
Junior Horticulturist
L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist
Troy M. Currence, B. S. Agr.††
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Assistant Plant Pathologist
L. H. Leonian, Ph. D.
Assistant Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwod, M. S. Agr.
Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D.
Associate Soil Technologist

*In co-operation with the U. S. Department of Agriculture, Washington, D. C.
**In co-operation with the State Department of Agriculture, Charleston, W. Va.
***Resigned September 1, 1925.
†In charge of the Maggie Sub-Station, Maggie, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††On leave of absence.

Varietal Experiments and First Generation Crosses in Corn

Corn is the most important cultivated crop from the standpoint of both acreage and value grown in West Virginia. Approximately one-fourth of the total area under cultivation in this state is used for the production of this crop. During the last five years there have been planted annually within the state, approximately 600,000 acres of corn with an average yield of about 34 bushels per acre. The estimates of the United States Department of Agriculture and the Fourteenth Census of the United States show that the acreage of corn has been reduced somewhat during the last fifteen years. In 1909 there were 676,311 acres of corn harvested as compared with 568,219 acres in 1919.

The value of the corn crop in West Virginia is far greater than the value of any other field crop grown within the state. The value of corn compared with the values of four other crops is shown in Table I.

TABLE I.—The Monetary Value of Corn, Oats, Wheat, Cultivated Grasses for Hay, and Tobacco Grown in West Virginia in 1909 and 1919.*

Crop	Value	
	1909	1919
Corn	$11,907,261	$29,768,131
Cultivated grasses for hay	7,318,162	18,334,421
Wheat	2,697,141	8,395,097
Oats	912,388	3,054,668
Tobacco	1,923,180	2,731,338

*From the Fourteenth Census of the United States.

The cultivated grasses listed in Table I consist largely of timothy and red clover grown alone and in mixtures. In 1909 the value of the corn crop was slightly more than one third, and in 1919 somewhat less than one third, the total value of all field and horticultural crops grown within the state during the two years respectively.

Most of the corn produced in West Virginia is grown in the western half of the state, particularly along the Ohio River. The section known as the Eastern Panhandle and the south eastern section of the state also produce considerable corn. The ten leading counties in the production of this crop are, in the order named: Jefferson, Wayne, Jackson, Berkeley, Mason, Marshall, Greenbrier, Lincoln, Braxton, and Roane.

OBJECTS OF EXPERIMENTS

One of the requirements for successful corn production is the selection of a variety best adapted to the particular conditions of soil and climate in which the crop is to be grown. With the aim of aiding the farmer in determining what varieties best meet his needs, the Department of Agronomy of the West Virginia Agricultural Experiment Station, in 1921 and 1922, started rather extensive varietal tests. Most of these tests have been carried on cooperatively in various sections of the state.* In addition to the cooperative experiments, varietal trials have been carried out on the Agronomy Farm and at the Maggie Substation.

In the cooperative experiments and in the experiments at the Maggie Substation, the main object was to compare the different varieties on the basis of yield of shelled corn per acre, whereas the varieties grown on the Agronomy Farm were compared from the standpoint of both yield of shelled corn and yield of forage (silage) per acre.

Another object of the varietal experiments was to compare the value of home grown seed with seed from some other source. Among the varieties grown on the Agronomy Farm were two commonly used as silage corn, which afforded an opportunity to make comparison between locally grown grain varieties and introduced silage varieties. In this experiment a variety of sunflowers also was grown for the purpose of making comparisons on the basis of yield of forage.

---

*The authors desire to acknowledge their indebtedness to the following persons who helped make the cooperative tests possible: D. R. Dodd, Extension Agronomy Specialist; R. M. Musser, County Agent, Greenbrier County; J. E. Romine, County Agent, Randolph County; C. G. Degen, County Agent, Berkeley County; W. H. Roberts, County Agent, Mercer County; E. G. Hibbs, County Agent, Brooke County; L. F. Sutton, Superintendent Reymann Memorial Farms; J. B. Sydenstricker; C. F. Hammond; A. H. Stuckey; J. A. Godfrey; O. B. Humphreys; O. H. Bowling; P. E. Wheeler; W. H. Sill; Will Finley; and L. J. Belcher.

In addition to the varieties, certain first generation crosses between varieties were included in the experiments in order to determine their relative value compared with that of the parents, particularly from the standpoint of yield and number of days required to mature. At the higher altitudes in West Virginia, the number of days required for maturity is a limiting factor in the production of corn. It was thought that first generation crosses between an early maturing flint corn and somewhat later maturing dent varieties might prove of value under these conditions.

METHODS USED IN EXPERIMENTS

Owing to the limited area of land available on the Agronomy Farm the experiments here were carried out on smaller plots than at the other places. Each variety was grown in three systematically distributed plots, each one of which consisted of four rows approximately 136 feet long and 3 feet and 6 inches apart. One-half of each plot (divided transversely) was planted in hills 3 feet and 6 inches apart, and the other half was planted in drilled rows with the plants 15 inches apart in the rows. An excess of seed was planted and when the corn was about six inches high it was thinned to two stalks per hill and to a single stalk in the drilled rows.

Notes were taken on average height of plant and days to maturity, and previous to harvesting a note was taken on the stand. No attempt was made to correct yield because of missing stalks or hills, but if a plot showed a relatively high percentage of missing plants it was eliminated or if the missing plants occurred mostly in a certain part of the plot that part only was eliminated. In general, the stand of corn obtained by the method outlined above was uniform and there were relatively few missing plants in the test plots.

The yield of each variety was based on the two inner rows (end plants were discarded) of each plot except where otherwise noted. The yield of forage was determined from the drilled rows and the yield of shelled corn from the rows planted by the hill method. A variety was considered sufficiently matured for the silo when the ears reached the "glazed stage" and at this time the two inner drilled rows of each plot were cut, weighed, and a sample taken for the determination of yield on an air-dry basis. A portion of the sample which previously had been run through a feed cutter was firmly tamped into two-quart Mason jars and later analyzed. Samples preserved in this way produced very satisfactory silage.

The yield of shelled corn per acre was based on that part of the plot planted by the hill method. When the two central rows of each plot were mature they were cut and shocked and later in the fall (late October or November) the corn was husked, weighed and a sample taken for the determination of percentage of moisture and the relative amount of shelled corn. In 1921 and 1922 yield was computed on the basis of air-dry shelled corn per acre and in 1923 and 1924 on the basis of shelled corn containing 14 per cent moisture.

The cooperative varietal experiments and the experiments at Maggie were carried on in a manner similar to that used on the Agronomy Farm except with regard to size of plots and number of replications. In general each plot consisted of four rows approximately 136 feet long and 3 feet and 6 inches apart. The corn was planted in hills 3 feet and 6 inches each way and thinned to two stalks per hill. Each variety was grown in four systematically distributed plots and the yield was determined on the basis of bushels of shelled corn per acre. A representative of the Agronomy Department was on hand to help plant the cooperative tests and again later to help husk, weigh, and sample the corn. The percentage of moisture and relative amount of shelled corn were determined at Morgantown. In case the above plan was not followed, a note explaining the particular procedure followed was made.

SOURCE OF SEED

The seed used in the varietal trials reported here was obtained from various places. In some cases the seed was obtained from the same original source each year and in other cases the seed had been produced on or near the Agronomy Farm since its original introduction. In the cooperative tests seed of the local varieties was obtained in the vicinity of the test and in most cases from the same source each year. In Table II. are listed the varieties (except the local varieties in the cooperative tests) together with the source of the seed used each year in the several varietal trials.

TABLE II.—Varieties and the Source of Seed Used in the Corn Varietal Experiments.

Varieties	Source of Seed for Each Year			
	1921	1922	1923	1924
Boone County White	Funk Bros. Seed Co. Bloomington, Ill.	Same as 1921	Agronomy Farm	Same as 1923
Blue Ridge	W. H. Turner & Son Afton, Virginia	Same as 1921	Same as 1921	Same as 1921
Clarage	F. E. Eichelberger Washington Court House, O.	Agronomy Farm	Same as 1922	Same as 1922
Cocke's Prolific	T. W. Wood & Sons Richmond, Va.	John Lewis Buckhannon, W. Va.	T. W. Wood & Sons Richmond, Va.	Same as 1923
Golden Glow	Jippa Wielinga Midway, Wis.	Agronomy Farm	Same as 1922	Same as 1922
Johnson County White		C. E. Troyer La Fontaine, Ind.	Agronomy Farm	Same as 1923
Leaming	Geo. S. Strosnider Waynesburg, Pa.	Same as 1921	Same as 1921	Same as 1921
Longfellow	R. Keeler Bridgewater, Conn.	Agronomy Farm	R. Keeler Bridgewater, Conn.	Agronomy Farm
Knight's White	L. N. Knight Maggie, W. Va.	Same as 1921	Same as 1921	Agronomy Farm
Silver King		Va. Exp. Sta. Blacksburg, Va.	Same as 1922	Same as 1922
Woodburn White Dent U. S. Selection No. 77		J. M. Brown Piketon, O.	Same as 1922	Same as 1922
Reid's Yellow Dent	Funk Bros. Seed Co. Bloomington, Ill.	Same as 1921	Agronomy Farm	Same as 1923
Minnesota No. 13		Univ. Farm St. Paul, Minn.	Same as 1922	Same as 1922
Mammoth Russian Sunflowers	T. W. Wood & Sons Richmond, Va.	Agronomy Farm	Same as 1922	Same as 1922

The varieties Blue Ridge and Cocke's Prolific were included in the tests to represent the silage type of corn. The other varieties listed in Table II are dent varieties with the exception of Longfellow which is a flint corn. The Mammoth Russian variety of sunflowers is also included in Table II. Knight's White is a large-eared, white dent corn that has been grown in the neighborhood of Maggie, West Virginia for a number of years. In that locality it is frequently used as a silage corn. Woodburn White Dent or U. S. Selection No. 77 is a relatively new variety of corn developed by the United States Department of Agriculture.

The crossed seed for the first generation crosses was produced on an isolated plot on the Agronomy Farm. The several dent varieties were grown in alternate rows with Longfellow Flint; the former being detasseled. In this way the dent varieties were prevented from forming pollen and the ears produced by them were the result of cross-pollination with Longfellow Flint.

EXPERIMENTS AT MORGANTOWN

In Table III are listed the varieties of corn, first generation crosses, and Mammoth Russian sunflowers included in the varietal experiments on the Agronomy Farm. In this Table the average number of days to maturity, average height, and average yield in bushels of shelled corn per acre are shown.

An examination of the second column of Table III shows that Woodburn White Dent, Knight's White, Cocke's Prolific, Johnson County White, Boone County White, and Blue Ridge are relatively late maturing varieties. Longfellow, the only flint corn in the test, is by far the earliest maturing variety. The other varieties of corn and first generation crosses range in average number of days to mature from 147 to 151 days. Sunflowers mature somewhat later than Longfellow flint corn.

It is interesting to compare the first generation crosses with the dent parents. Reid's Yellow Dent crossed with Longfellow flint matured on the average 4 days earlier; Boone County White with Longfellow 7 days earlier; Blue Ridge with Longfellow 7 days earlier; and Cocke's Prolific with Longfellow 11 days earlier than their respective dent parents.

TABLE III.—Yield in Bushels of Shelled Corn Together With Height, and Days to Mature, of Corn Varieties Grown on the Agronomy Farm.

Varieties	Average No. of Days to Mature, 1922-23-24	Average Height in Feet, 1922-23-24	Yield Per Acre in Bushels 1921	1922	1923	1924	Average Yield 1921-22-23-24 in Bushels	Average Yield 1922-23-24 in Bushels
Leaming	150	8.9	45.9	71.3	59.8	41.9	54.7	57.7
Reid's Yellow Dent	151	9.1	45.8	83.0	46.1	36.4	52.8	55.2
Woodburn White Dent	160	9.3		79.1	46.3	38.0*		54.5
Boone County White	156	9.4	45.1	83.4	49.8	26.0	51.1	53.1
Blue Ridge	156	10.0	39.9	78.3	47.4	31.5	49.3	52.4
Clarage	150	8.6	47.6	72.8	41.1	37.6	49.8	50.5
Johnson County White	158	9.3		73.4	46.4	29.3		49.7
Reid's Yellow Dent x Longfellow	149	8.6		63.0	44.2	33.9		47.0
Boone Co. White x Longfellow	147	8.5		64.1	46.9	35.2		48.7
Knight's White	160	9.1	47.2	27.1	43.0	23.1*	46.9	46.7
Blue Ridge x Longfellow	149	8.7		58.3	43.5	33.7		45.2
Cocke's Prolific x Longfellow	149	9.2		57.7	37.9	26.6		40.7
Cocke's Prolific	160	9.5	35.2	66.3	32.3	20.0	38.5	39.5
Longfellow	130	7.0	12.1	16.3	17.5	17.4*	15.8	17.1
Sunflowers (Mammoth Russian)	136	7.3	113.8	75.0	56.4	58.0	78.3	66.5

*Yield in 1924 based on the average of two plots only.

With regard to average height most of the varieties range from 8.5 feet to 9.5 feet. The average height of the tallest variety, Blue Ridge, was 10 feet and that of the shortest variety, Longfellow, was 7 feet. The first generation crosses were on the average somewhat shorter than their respective dent parents.

In the last column of Table III the average yields in bushels of shelled corn per acre of the several varieties grown during the three years 1922 to 1924 inclusive are tabulated. Some of the varieties were grown also in 1921. The average yields of these varieties for four years are listed in next to the last column of the table.

In interpreting yield data such as are presented in Table III it is necessary to take into consideration not only the averages but also the variability of the yields throughout the entire period of the experiment. For example, considering the two varieties which rank first and second in yield from the standpoint of both three-year and four-year averages, it is evident that in 1921 the yields of the two varieties were practically identical, in 1922 Reid's Yellow Dent exceeded Leaming by 11.7 bushels and in 1923 and 1924 Leaming

exceeded Reid's Yellow Dent by 13.7, and 5.5 bushels during the two years respectively. It is possible to apply a mathematical method of analysis to data such as these and determine the significance of the difference between the average yields. The method is briefly discussed at the end of this bulletin in the appendix. It suffices here to state that when the data on yield of these two varieties are so analyzed, the difference between their average yields is found to be not significant. In other words, should the above experiment be repeated under similar circumstances it would occasion no surprise if in this second experiment the average yield of Reid's Yellow Dent exceeded that of Leaming. It is reasonable to expect that the more consistent the difference in yield between varieties throughout a period of years and the greater the difference between their average yields, the more significant the difference becomes. With the foregoing considerations in mind it is obvious that one may state with a greater degree of certainty, that under the given conditions the three or four highest yielding varieties are superior in yielding capacity to the three or four next highest yielding varieties, than that Leaming possesses greater yielding capacity than Reid's Yellow Dent. The yield data of Table III as well as those contained in subsequent tables are interpreted from this viewpoint.

The four varieties grown on the Agronomy Farm which produced the highest average yield of shelled corn per acre are Leaming, Reid's Yellow Dent, Woodburn White Dent, and Boone County White. Knight's White produced a relatively low average yield primarily because of the unfavorable growing conditions, particularly for late maturing varieties, in 1924. Of the late maturing varieties the yielding ability of Woodburn White Dent seems to have been affected least by the adverse conditions of 1924. Longfellow flint corn has been a low yielder consistently throughout the duration of the experiment. Mammoth Russian sunflowers yielded an average of 78.3 bushels (20 pounds per bushel) for the four-year period.

The average yields of the first generation crosses are considerably higher than the average yield of the Longfellow parent but somewhat lower (with one exception) than their respective dent parents. The average yield (as given in the last column of Table III) of Reid's Yellow Dent crossed with Longfellow is 6.5 bushels; of Boone County White with Longfellow 6.1 bushels; and of Blue Ridge with Longfellow, 7.2 bushels less than that of their respective dent parents. The average yield of Cocke's Prolific and Cocke's Prolific crossed with Longfellow are not very different. In general

the first generation crosses tended to yield less but matured somewhat earlier than their respective dent parents.

In order to make further comparisons between the first generation crosses and their parents, certain measurements were made on random samples of ears taken from the crop grown in 1922. The characters considered were length of ear, circumference of ear at about one-third of the distance from the base to the tip and the number of rows of kernels per ear. The data are presented in Table IV.

TABLE IV.—The Average Length, Average Circumference, and Average Number of Rows of Kernels of Ears of Corn Taken at Random From Certain First Generation Crosses and Their Parents Grown in 1922.

Varieties	Number of Ears Considered	Average Length in Inches	Average Circumference in Inches	Number of Rows of Kernels
Boone County White	107	8.86±0.10	7.13±0.04	16.86±0.16
Boone Co. White x Longfellow	111	9.42±0.11	5.93±0.03	11.77±0.11
Blue Ridge	122	8.29±0.08	7.05±0.03	12.23±0.10
Blue Ridge x Longfellow	115	9.04±0.09	5.95±0.03	10.40±0.10
Cocke's Prolific	153	8.45±0.07	5.39±0.02	11.06±0.09
Cocke's Prolific x Longfellow	134	9.56±0.11	5.37±0.02	9.81±0.09
Reid's Yellow Dent	104	8.75±0.08	6.70±0.03	17.29±0.14
Reid's Yellow Dent x Longfellow	111	9.63±0.10	5.75±0.03	11.86±0.12
Longfellow	40	9.52±0.17	4.78±0.04	8.00±0.00

An examination of the third column of Table IV shows that with regard to average length of ears the first generation crosses approached more closely to Longfellow, the flint parent, than to their respective dent parents. In no case is the difference between the average length of ears of a first generation cross and its flint parent significant. With regard to average circumference of ears (fourth column) the first generation crosses, with one exception, occupy a position midway between their respective parents. The average circumference of ears of Cocke's Prolific crossed with Longfellow does not differ significantly from that of Cocke's Prolific. In the average number of rows of kernels per ear (fifth column) also the first generation crosses occupy an intermediate position between their respective parents.

The yield in tons per acre of green and air dry forage and the average number of days from planting until harvest for each variety and each first generation cross may be found in Table V. The

harvesting was done when the ears reached the "glazed stage," the usual time of cutting for the silo. The sunflowers were cut at the hard dough stage.

It may be seen from the second column of Table V that Cocke's Prolific, Woodburn White Dent, Knight's White, and Johnson County White were latest in maturing and that Blue Ridge and Boone County White were next. It will be observed that these varieties also were the highest yielding sorts in the experiment. Longfellow flint corn and Mammoth Russian sunflowers matured first. In general the first generation crosses were ready for the silo considerably earlier than the dent parents. Cocke's Prolific crossed with Longfellow matured on the average 12 days; Boone County White with Longfellow 13 days; Reid's Yellow Dent with Longfellow 7 days; and Blue Ridge with Longfellow 13 days earlier than their respective dent parents. It is interesting to note that in general the difference is greater between the first generation crosses and the dent parents with regard to the growing period for silage than it is with regard to the growing period for grain.

TABLE V.—Yield in Tons of Green and Air Dry Forage, and Days to Mature of Corn Varieties Grown on the Agronomy Farm.

Varieties	Average Number of Days to Silage Stage 1922-23-24	Tons of Forage per Acre, Green and Air Dry, for Each Year								Average Tons Forage per Acre			
		1921		1922		1923		1924		1922-23-24		1921-22-23-24	
		Green	Air Dry	Green	Air Dry	Green	Air Dry	Green	Air Dry	Green	Air Dry	Green	Air Dry
Cocke's Prolific	143	9.29	3.19	15.72	5.45	10.35	3.07	9.63	3.30	11.25	3.75	11.90	3.94
Woodburn White Dent	143			14.44	5.07	12.24	3.42	10.47	2.98			12.38	3.82
Knight's White	143	9.76	3.22	15.01	4.88	11.21	3.44	8.66	2.89	11.16	3.61	11.63	3.74
Boone Co. White	137	8.22	2.60	14.76	4.84	11.93	3.42	8.66	2.70	10.89	3.39	11.78	3.65
Johnson Co. White	143			12.93	4.66	11.34	3.56	8.28	2.51			10.85	3.58
Blue Ridge	138	8.38	2.61	14.24	4.70	12.04	3.38	9.43	2.64	11.02	3.33	11.90	3.57
Reid's Yellow Dent	131	6.74	2.27	12.97	4.63	11.04	3.14	9.16	2.75	9.98	3.20	11.06	3.51
Leaming	129	6.63	2.63	14.24	4.51	11.26	3.04	8.28	2.71	10.10	3.22	11.26	3.42
Clarage	131	7.97	2.99	13.86	4.15	11.87	2.95	9.10	2.43	10.70	3.13	11.61	3.18
Cocke's x Longfellow	131			13.01	4.30	8.74	2.50	9.57	2.58			10.44	3.13
Boone Co. White x Longfellow	124			13.31	3.83	11.35	2.86	8.92	2.46			11.19	3.05
Reid's Yellow Dent x Longfellow	124			12.25	3.69	10.83	2.75	8.47	2.30			10.52	2.91
Blue Ridge x Longfellow	125			13.03	3.96	8.35	2.06	8.28	2.37			9.89	2.86
Sunflowers (Mammoth Russian)	116	10.51	2.29	18.23	2.91	10.33	1.82	11.90	2.05	12.74	2.27	13.49	2.26
Longfellow	114	4.49	1.42	8.27	1.81	6.10	1.27	5.93	1.39	6.20	1.47	6.77	1.49

In the last column of Table V the average yields in tons per acre of air dry forage of the several varieties for the years 1922 to 1924, inclusive, are shown. Cocke's Prolific, Woodburn White Dent, Knight's White, and Boone County White rank first, second, third, and fourth, respectively, with regard to average yield. Anyone of these varieties may be expected to produce a satisfactory tonnage under conditions similar to those under which they were grown. Longfellow flint and Mammoth Russian Sunflowers rank last and next to last with respect to average yield. The first generation crosses yielded less than their dent parents but matured considerably earlier. In the third column from the right of the table the average yield in tons of air dry forage of the varieties which were grown for four years are listed. The relative rank of the varieties on the basis of a four-year-average yield is practically the same as on the basis of a three-year-average yield.

In next to the last column the average yields in tons per acre of green forage are listed. In general, the yields on this basis correspond roughly to the yields on an air dry basis but there is one notable exception, namely, Mammoth Russian sunflowers. Although the sunflowers produced on the average the greatest tonnage of green material they rank near the bottom in tonnage of air dry forage. Of the several corn varieties Woodburn White Dent ranks first on the basis of average green weight but there are several varieties which do not differ significantly from it in this respect.

In choosing a variety of corn which is to be grown for the silo it is important to consider not only gross tonnage from the standpoint of both green and air dry material but also to consider the feeding value per acre. This may best be done by suitable feeding experiments. However, in the absence of such expriments a chemical analysis of the silage may be fairly indicative of relative value.

It has been mentioned above that a sample of the green forage of each of the fifteen varieties grown in this experiment was firmly tamped into two-quart Mason jars and later analyzed. When the samples preserved in this way were analyzed they could not be distinguished from ordinary silage.* The percentage of protein, fat,

*All analyses were made in duplicate by Mr. T. J. Cochran of the Agricultural Chemistry Department to whom the authors are greatly indebted.

and carbohydrates based on the air dry silage were multiplied by the yields of air dry forage (Table V) to obtain the yields of the nutrients per acre. The results are presented in Table VI.

In the first column of Table VI the varieties are listed according to rank with respect to their total average production of protein, fat, and nitrogen free extract, which is shown in the last column of the table. It will be noted that the rank of the varieties with respect to the average annual production of these three nutrients corresponds roughly with the rank of the varieties with respect to the average yield of air dry forage (Table V). In both tables Cooke's Prolific, Woodburn White Dent, Knight's White, Boone County White and Johnson County White occupy the first five places, although the order of the varieties is not the same in both tables.

With respect to average production of protein in pounds per acre, as shown in the fifth column of Table VI, Cocke's Prolific, Woodburn White Dent, Johnson County White, and Leaming were the highest yielders. Sunflowers produced the highest yield of fat, as shown in the ninth column of this table. Johnson County White and Cocke's Prolific each produced on the average 213.7 pounds of fat per acre, which was 31.6 pounds less than that produced by the sunflowers. The average yield in pounds of nitrogen free extract (sixth column from the right) corresponds closely to the total average yield of the three most important nutrients (last column). Cocke's Prolific produced a considerably higher average yield of fiber than any other variety (next to last column). The sunflowers produced relatively more fiber in proportion to the yield of air dry forage than was produced by any of the varieties of corn.

Corn Varieties Grown on the Agronomy Farm in 1923.

TABLE VI.—Yield per Acre in Pounds of Protein, Fat, and Carbohydrates of the Corn Varieties Grown on the Agronomy Farm.

Varieties	Pounds per Acre of Protein, Fat, and Corbohydrates for Three Years, 1922, 1923, and 1924, and Averages																
	Protein				Fat				Carbohydrates								Total of Average Protein, Fat, and N-free Extract
									Nitrogen Free Extract				Fiber				
	1922	1923	1924	Ave.	1922	1923	1924	Ave.	1922	1923	1924	Ave.	1922	1923	1924	Ave.	
Woodburn White Dent	685	458	325	489.3	271	181	148	200.0	6250	4038	3600	4629.3	2014	1255	1232	1500.3	5318.6
Cocke's Prolific	824	424	352	533.3	373	114	154	213.7	6580	3041	3775	4465.3	2161	1715	1552	1809.3	5212.3
Johnson Co. White	640	464	324	476.0	295	209	137	213.7	5936	4226	3114	4425.3	1488	1292	892	1224.0	5115.0
Knight's White	660	347	325	444.0	257	140	133	176.7	5956	3944	3494	4464.7	1952	1582	1230	1588.0	5085.4
Boone County White	582	405	313	433.3	253	143	118	171.3	6030	3900	3280	4403.3	1850	1518	1108	1492.0	5007.9
Blue Ridge	635	348	297	426.7	303	169	145	205.7	5852	3902	3207	4320.3	1679	1459	1037	1391.7	4952.7
Reid's Yellow Dent	562	365	312	413.0	292	120	145	185.7	5823	3500	3434	4252.3	1639	1268	1084	1330.3	4851.0
Leaming	669	393	346	469.3	293	169	158	206.7	5389	3512	3479	4126.7	1574	1098	944	1205.3	4802.7
Clarage	558	381	300	413.0	251	152	137	180.0	5237	3471	2851	3853.0	1409	1098	962	1156.3	4446.0
Boone Co. x Longfellow	525	361	304	396.7	217	150	139	168.7	4679	3419	3015	3704.3	1456	1041	938	1145.0	4269.7
Cocke's x Longfellow	596	299	282	392.3	242	135	111	162.7	5145	2814	3018	3659.0	1845	1140	1199	1394.7	4214.0
Reid's x Longfellow	421	344	261	342.0	217	131	135	161.0	4748	3186	2874	3602.7	1265	1072	840	1059.0	4105.7
Blue Ridge x Longfellow	598	255	274	375.7	257	108	127	164.0	4747	2259	2889	3298.3	1412	828	929	1056.3	3838.0
Sunflowers	430	284	337	350.3	269	202	265	245.3	2522	1562	1743	1942.3	1783	1076	1168	1342.3	2537.9
Longfellow	337	194	228	253.0	106	49	72	75.7	2041	1415	1550	1668.7	758	481	516	585.0	1997.4

EXPERIMENTS AT THE MAGGIE SUBSTATION

The Maggie Substation is located near the Ohio River in Mason County. The varietal experiments here, which were carried on for two years only, were located on first bottom land that is highly productive. The growing season is somewhat longer at Maggie than at Morgantown and for this reason relatively later maturing varieties may be grown. The varieties which were included in the test and their yields are shown in Table VII.

TABLE VII.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown at the Maggie Substation.*

Varieties†	Yield Per Acre in Bushels		Average Yield in Bushels, 1922-23
	1922‡	1923‡	
Woodburn White Dent	88.3	92.5	90.4
Boone County White	80.7	79.4	80.1
Golden Beauty (local)	80.0	72.6	76.3
Reid's Yellow Dent	76.8	75.7	76.3
Johnson County White	76.4	73.9	75.2
Leaming	67.1	76.3	71.7
Success (local)	75.2	------	------
Leaming x Longfellow	------	59.1	------

*All yields calculated on air dry basis.
‡Yields based on the average of five plots.
†Golden Beauty obtained from C. W. Brown; Success obtained from L. N. Knight.

Woodburn White Dent or U. S. Selection No. 77 yielded in 1922 7.6 bushels and in 1923 13.1 bushels more than Boone County White, the second highest yielding variety during the two years respectively. In view of the fact that the yields of the two varieties in each of the two years the experiment was carried on are based on the average of five plots and the further fact that a rather marked difference in yield was obtained, it seems reasonable to attach some s.ignificance to the results.

It will be recalled that the seed of Woodburn White Dent was obtained from Mr. J. M. Brown, Piketon, Ohio (Table II), where it was grown under conditions very similar to those which are found at Maggie. This fact undoubtedly accounts at least partially for the superiority in yield of this variety over some of those listed in Table VII, but it does not account for the difference in yield between Woodburn White Dent and Golden Beauty. Golden Beauty had been grown in the vicinity of the Maggie Substation for a number

of years and was considered a high yielding variety of corn. Although the data on yield of the several varieties in the test cover a two-year period only, they indicate that Woodburn White Dent possesses a yielding capacity, for the particular conditions, greater than any other variety in the experiment

EXPERIMENTS IN BERKELEY COUNTY

In Berkeley County there were two co-operative varietal experiments—one on the farm of Mr. C. F. Hammond and the other on the farm of Mr. A. H. Stuckey. Both of these experiments were carried on during 1922 to 1924 inclusive.

In Table VIII. are listed the seven varieties of corn which were included in the test on the Hammond Farm. The varieties with the word "local" after them were obtained in the locality where the experiment was conducted. Seed of the other varieties was obtained from the sources already mentioned.

TABLE VIII.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the Hammond Farm in Berkeley County.

Varieties*	Yield Per Acre in Bushels			Average Yield in Bushels, 1922-23-24
	1922	1923	1924	
Leaming (local)	66.1	58.5	46.5	57.0
Leaming	61.7	53.0	45.6	53.4
Boone County White	65.4	53.8	39.7	53.0
Reid's Yellow Dent	60.9	57.0	40.2	52.7
Reid's Yellow Dent (local)	61.1	58.2	38.1	52.5
Boone County White (local)	62.1	53.0	41.1	52.1
Johnson County White	61.8	55.9	33.0	50.2

*Leaming (local) obtained from C. F. Hammond; Reid's Yellow Dent (local) obtained from H. L. Smith; Boone County White (local) obtained from T. H. Wilson.

In the last column of Table VIII the average yields in bushels of shelled corn per acre are shown. There is a difference between the average yields of the highest and lowest producing sorts of only 6.8 bushels. The local strain of Leaming, which ranked the highest in the test, has been grown by Mr. Hammond for several years. It yielded on the average 3.6 bushels more than the other strain of Leaming. Moreover, the second, third, and fourth columns show that the difference in yield between these two strains is fairly consistent throughout the three years of the experiment. According

to Students' Method (see appendix) of analyzing results such as these the chances are about 15 to 1 that the difference in yield between the two strains of Leaming is truly significant. In other words the chances are 15 to 1 that the difference in yield obtained here is owing to a real difference in the inherent yielding capacity of the two varieties when grown under this particular environment and not owing solely to chance or accident. The average yields of the two strains of Reid's Yellow Dent do not differ significantly. The relatively low average yield of Johnson County White is owing largely to the low yield produced by this variety in 1924 (fourth column.) The season of 1924 was rather adverse for late maturing varieties of corn such as Johnson County White.

The experiment on the Stuckey farm included the same varieties that were grown on the Hammond farm with the addition of a fourth local variety, Blue Dent. The varieties and yields are shown in Table IX.

TABLE IX.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the Stuckey Farm in Berkeley County.

Varieties*	Yield Per Acre in Bushels			Average Yield in Bushels,
	1922	1923	1924	1922-23-24
Leaming (local)	40.2	38.6	22.4	33.7
Boone County White	35.7	44.7	18.7	33.0
Leaming	34.7	39.9	22.0	32.2
Reid's Yellow Dent	29.5	44.1	20.2	31.3
Boone County White (local)	35.2	41.6	15.9	30.9
Johnson County White	34.2	44.3	13.7	30.7
Blue Dent (local	37.1	32.7	21.4	30.4
Reid's Yellow Dent (local)	30.4	39.9	20.2	30.2

*Leaming (local) obtained from C. F. Hammond; Reid's Yellow Dent (local) obtained from H. L. Smith; Boone County White (local) obtained from T. H. Wilson; Blue Dent obtained from A. H. Stuckey.

The yields given in the last column of Table IX show an extreme difference of only 3.5 bushels between the variety (local Leaming), which produced the highest, and the one (local Reid's Yellow Dent), which produced the lowest average yield of shelled corn per acre during the three years 1922 to 1924, inclusive. This difference is not significant. It is interesting to note that on the basis of average yield the local strain of Leaming again ranks first. An examination of the second, third, and fourth columns shows that the yields in any one year were quite variable and also that the relative yields of the varieties from year to year were not very consistent.

EXPERIMENTS IN HARDY COUNTY

The varietal test in Hardy County was carried on for two years only. The work was done on the Reymann Memorial Farm near Wardensville and under the immediate direction of Mr. L. F. Sutton, superintendent of the farm. The varieties and yields are recorded in Table X.

TABLE X.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the Reymann Memorial Farm in Hardy County.

Varieties*	Yield Per Acre in Bushels		Average Yield in Bushels, 1922-1923
	1922†	1923‡	
Johnson County White	55.7	50.5	53.1
Boone County White	55.2	46.4	50.8
Brill Corn (local)	53.4	40.5	47.0
Reid's Yellow Dent	49.1	39.3	44.2
Leaming	43.4	43.3	43.4
Cocke's Prolific	43.4	35.9	39.7
Boone County White x Longfellow	41.4	36.7	39.1
Leaming x Longfellow	34.7	33.8	34.3
Longfellow	10.4	11.5	11.0
Silver King	......	41.2	......
Yellow Cap Red (local)	......	41.7	......

†Yield of each plot based on one central row only.
‡Yield of each variety based on a single plot only.
*Brill corn (local) obtained from Brill Bros; Reid's Yellow Dent (local) obtained from Reymann Memorial Farm; Yellow Cap Red (local) obtained from Winchester Seed Corporation.

Owing to local conditions it was found necessary to modify the original plan of the experiment. In 1922 the yield of each variety was based on the average yield of four central rows from as many plots, one row from each plot. The year following the yield was based on two central rows of a single plot only. In view of these facts the results of this experiment are not very trustworthy. It is interesting to note, however, that the yields in 1922 (second column of Table X) and in 1923 (third column) are fairly consistent as to relative rank.

EXPERIMENTS IN GREENBRIER COUNTY

During 1922 two varietal experiments were carried on in Greenbrier County, one on the farm of Mr. J. B. Sydenstricker and one on the farm of Mr. O. B. Humphreys. In 1923 and 1924 a varietal test was conducted on the Sydenstricker farm only. The varieties grown and the yields obtained are shown in Table XI.

TABLE XI.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the J. B. Sydenstricker Farm in 1922, 1923, and 1924; and on the Humphrey Farm in 1922, Both in Greenbrier County.

Varities*	Yield Per Acre in Bushels			Average Yield in Bushels, 1922-23-24	Yield 1922‡
	1922	1923†	1924		
Local Yellow	55.1	53.9	14.1	41.0	50.7
Leaming	44.4	52.3	15.0	37.2	49.8
Local White	51.4	48.0	10.3	36.6	48.4
Reid's Yellow Dent	52.7	43.0	6.5	34.1	44.8
Silver King	44.0	45.1	11.6	33.6	39.1
Clarage x Longfellow	39.1	45.5	15.0	33.2	38.2
Leaming x Longfellow	38.4	47.5	11.9	32.6	34.3
Clarage	36.9	38.4	7.6	27.6	34.3
Longfellow	7.9	16.5	9.3	11.2	11.8

†In 1923 plots were 105 feet long.
‡Yields obtained on the Humphrey farm.
*Local Yellow obtained from C. W. Handley in 1922 and R. A. Anderson in 1923 and 1924. Local White obtained from C. W. Handley in 1922 and S. W. Anderson in 1923 and 1924.

In next to the last column of Table XI the average yield in bushels of shelled corn per acre for the varieties grown on the Sydenstricker farm are shown. Local Yellow, Leaming, and Local White gave the highest average yields. According to Students' Method the difference in yield between Local Yellow and Local White is probably significant but between Local Yellow and Leaming the difference in yield is not significant. The average yield of the first generation cross, Clarage crossed with Longfellow, is 5.6 bushels greater than Clarage, the dent parent, and 22 bushels greater than Longfellow, the flint parent. The chances are about 24 to 1 that the former difference is significant. Here is an instance of a first generation cross that seems to possess greater yielding capacity than either of its parents.

In the last column of the table the average yields of the varieties grown on the Humphrey Farm in 1922 are shown. The four varieties, Local Yellow, Leaming, Local White, and Reid's Yellow Dent, which produced the highest average yields here, also produced the highest average yields on the Sydenstricker Farm during the same year (second column).

EXPERIMENTS IN MERCER COUNTY

The environmental conditions for the production of corn in Mercer County are somewhat similar to those of Greenbrier County. In view of this fact the same varieties were tested in both counties. The results of the work in Mercer County are recorded in Table XII.

The test was conducted on a different farm each year and for this reason the averages presented in fifth and sixth columns are not very trustworthy. The average yields in 1922 (second column) and in 1924 (fourth column) are based on the total production of all four rows of each plot, instead of on the two central rows as in most of the varietal experiments.

TABLE XII.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the County Farm in 1922, on the Bowling Farm in 1923, and on the Belcher Farm in 1924, All in Mercer County.

Varieties*	Yield Per Acre in Bushels			Average Yield in Bushels, 1922-1923	Average Yield in Bushels, 1922-23-24
	1922†	1923	1924†		
Silver King	41.2	48.2	32.0	44.7	40.5
Leaming	36.4	44.3	......	40.4	......
Reid's Yellow Dent	38.6	41.9	......	40.3	......
Clarage x Longfellow	38.8	41.4	38.4	40.1	39.5
Local White	37.8	41.9	44.0	39.9	41.2
Leaming x Longfellow	37.6	41.5	35.4	39.6	38.2
Clarage	34.2	34.7	......	34.5	......
Longfellow	26.6	21.0	27.7	23.8	25.1
Local Yellow	......	......	39.9	......	......

*Local Yellow obtained from W. P. Winfrey; Local White obtained from L. J. Belcher.
†Yield of each plot based on all four rows instead of the two central rows only.

An examination of Table XII shows that Silver King, an early maturing white dent corn, yielded consistently high on both the County Farm in 1922 and the farm of Mr. O. H. Bowling in 1923, but produced a relatively low yield the next year on the farm of Mr. L. J. Belcher. In the test at the last named place (fourth column), Local White, Local Yellow, and Clarage crossed with Longfellow were the three highest yielders. In general, the results of the varietal experiments in 1922 and 1923 agree with each other more closely than they do with the results of 1924. It will be recalled that the season of 1924 was not favorable to corn production . In this year the Reid's Yellow Dent, Leaming, and Clarage did not mature and were not harvested.

In the fifth column may be found the average yield of the varieties grown in 1922 and 1923. Of the eight varieties grown during this time, six produced satisfactory average yields. The extreme difference between the average yields of these six varieties is 5.1 bushels. According to Students' Method the odds are about 10 to 1 that this difference is significant. The average yield of Clarage crossed with Longfellow exceeded that of Clarage by 5.6 bushels. Although this difference is based on a two-year average only, it is rather significant that in this experiment as well as the one in Greenbrier County, the first generation cross exceeded the yield of either of its parents.

EXPERIMENTS IN BROOKE COUNTY

The varietal tests in Brooke County were carried on for two years only; in 1922 on the farm of Mr. W. H. Sill and in 1923 on the farm of Mr. Will Finley. The yields of the varieties grown are recorded in Table XIII.

TABLE XIII.—Yield Per Acre in Bushels of Shelled Corn of Varieties Grown on the Sill Farm in 1922, and on the Finley Farm in 1923, Both in Brooke County.

Varieties*	Yield Per Acre in Bushels		Average Yield in Bushels, 1922-23
	1922	1923	
Hybrid Yellow Dent (local)	53.3	54.1	53.7
Red Top Yellow Dent (local)	51.1	50.7	50.9
Reid's Yellow Dent (local)	49.3	50.7	50.0
Leaming	49.1	49.2	49.2
Reid's Yellow Dent	45.8	50.7†	48.3
Boone County White	50.6	36.7	43.7
Johnson County White	48.3	36.6	42.5

*Hybrid Yellow Dent obtained from J. T. Burge; Red Top Yellow Dent obtained from W. H. Sill; Reid's Yellow Dent local obtained from S. C. Gist, Jr.

†Yield based on the average of three plots only.

An examination of the second and third columns of Table XIII shows that the yields for the two-year period are fairly consistent. The three local sorts were among the highest yielding varieties each year. This fact is also shown by the average yields listed in the fourth column. The three local varieties produced an average of 53.7, 50.9, and 50.0 bushels of shelled corn per acre, whereas Reid's Yellow Dent and Leaming gave average yields of 49.2 and 48.3 bushels

respectively. The differences in average yield between these five varieties are not very significant in view of the fact that they are based on tests carried on for two years only. Boone County White and Johnson County White failed to mature in 1923, which fact accounts for the relatively low yields in that year.

EXPERIMENTS IN RANDOLPH COUNTY

The altitude of most of the farm land in Randolph County is relatively high and therefore not adapted to growing late maturing corn. The varietal experiments in this county were carried on for three years on the County Farm. The varieties grown and yields obtained are listed in Table XIV.

TABLE XIV.—Yields Per Acre in Bushels of Shelled Corn, of Varieties Grown on the County Farm in Randolph County.

Varieties*	Yield Per Acre in Bushels			Average Yield in Bushels, 1922-23-24
	1922	1923†	1924†	
Silver King	64.4	39.4	44.2	49.3
Golden Glow	57.2	41.9	47.0	48.7
Shoe Peg (local)	50.8	47.1	45.3	47.7
Golden Glow x Longfellow	56.4	43.5	41.0	47.0
Minnesota No. 13	46.6	31.9	49.9	42.8
Clarage x Longfellow	51.5	43.1	33.3‡	42.6
Clarage	57.8	34.7	25.4‡	39.3
Longfellow	22.7	18.4‡	......	......
Crawford White Dent (local)	......	......	40.8	......

*Shoe Peg obtained from County Farm; Crawford White Dent obtained from Herbert Crawford.

†Yield of each plot based on all four rows instead of the two central rows only.

‡Yield based on the average of three plots only.

The second, third, and fourth columns of Table XIV show that the relative rank of the several varieties with regard to yield is not consistent. The highest yielders in 1922 were Silver King, Clarage, and Golden Glow; in 1923 Shoe Peg and Golden Glow crossed with Longfellow, and in 1924 Minnesota No. 13, Golden Glow, and Shoe Peg. The two varieties last named are the only ones that were among the three highest yielding varieties in two out of the three years the test was carried on. For the above reasons the average yields in the fifth column are not very trustworthy. It is interesting to note that the first generation cross (Clarage x Longfellow) again exceeded the average yield of its higher yielding parent (Clarage) by 3.3 bushels.

SUMMARY

1.—Corn varietal experiments were carried on from two to four years on the Agronomy Farm near Morgantown and in the following counties: Mason, Berkeley, Hardy, Greenbrier, Mercer, Randolph, and Brooks.

2.—On the Agronomy Farm, Leaming, Reid's Yellow Dent, Woodburn White Dent (U. S. Selection No. 77), and Boone County White produced the highest average yields of shelled corn per acre, whereas Cocke's Prolific Woodburn White Dent, Knight's White, and Boone County White produced the highest average yields of air dry forage (cut at the "ear-glazed" stage) per acre. On the basis of the four-year-average yield of air dry forage, Leaming and Reid's Yellow Dent produced approximately one-half ton per acre less than Cocke's Prolific, the highest yielding variety.

3.—The first generation crosses between Longfellow flint and certain dent varieties grown on the Agronomy Farm, in general, yielded both in grain and air dry forage somewhat less than their respective dent parents but matured somewhat earlier.

4.—Mammoth Russian sunflowers on the Agronomy Farm produced the highest average yield per acre of green forage, but on the basis of air dry forage the average yield was next to the lowest of all the varieties in the test. Longfellow flint corn produced less air dry forage per acre than was produced by the sunflowers.

5.—The total average yields of protein, fat, and nitrogen free-extract of the several varieties grown on the Agronomy Farm correspond approximately to the average yields of the air dry forage. The sunflowers produced relatively more fat and crude fiber in proportion to the amount of dry forage than was produced by any of the varieties of corn.

6.—At the Maggie Substation, Woodburn White Dent (U. S. Selection No. 77), on the basis of a two-year average yield, produced 10.3 bushels per acre more than any other variety in the test.

7.—The results of the co-operative varietal experiments show in general that local high yielding varieties or strains of corn produce as well as, and sometimes better than, high yielding varieties or strains introduced from elsewhere.

8.—The experiments in Berkeley County did not reveal any striking differences in average yields between any of the varieties in the tests. Two strains of Leaming and one each of Boone County White and Reid's Yellow Dent produced the highest average yields of shelled corn per acre on both the Hammond and Stuckey farms.

9.—In Greenbrier County a local yellow strain, a local white strain, and the Leaming variety obtained from Mr. George S. Strosnider near Waynesburg, Pennsylvania, produced the highest average yields of shelled corn per acre.

10.—The variety Silver King, which is a white dent corn, produced the highest yield of grain in both 1922 and 1923 in the experiments in Mercer County.

11.—In Randolph County the varieties Silver King, Golden Glow, and Shoe Peg, and the first generation cross of Golden Glow and Longfellow all produced satisfactory yields of grain.

12.—In Brooke County the three local strains of corn produced the highest average yields of grain. The introduced strains of Leaming and Reid's Yellow Dent, however, did not produce significantly lower yields than the local strains.

13.—Johnson County White, Boone County White, and Brill Corn produced the highest average yields of shelled corn in the varietal experiments on the Reymann Memorial Farm in Hardy County.

14.—The first generation cross of Clarage and Longfellow produced a higher average yield of shelled corn per acre than either of its parents in the three counties where they were compared, namely, Greenbrier, Mercer, and Randolph.

APPENDIX

During the last few years considerable has been written concerning the advantages and disadvantages of the probable error in interpreting field experiments. At present most agronomists use this criterion in some form as an aid in determining the significance of yield obtained in plot experimentation. Much of the adverse criticism that has been aimed at the probable error concept is owing to the lack of sympathetic understanding and an appreciation of its true value. The statistical method of analysis as an end in itself is of no particular interest to the agronomist, but as an aid in interpreting results of field experiments it becomes of great importance.

One of the greatest advantages of the statistical method of analysis is that it tends to remove the "personal equation" from the interpretation of experimental results. What may seem like a significant difference to one investigator may not seem so to another. One has only to examine the pages of a few bulletins presenting the results of agricultural experiments to be convinced of this fact.

While it is true that there are instances in the agricultural literature where the particular use that has been made of the probable error is questionable, it is true also that there are many more instances where the use of the probable error would have prevented the deduction of erroneous conclusions. A statistically significant difference cannot mean more than the data on which it is based. If the particular method used in determining the significance of the difference has been wrongly applied, that is the fault of the investigator and not of the method. Experimental results should be analyzed in such a way as to insure reaching the most trustworthy conclusions. Any method which reduces the amount of "guessing" to a minimum is justified.

In field experiments such as varietal trials the investigator is frequently confronted with the necessity of using a small number of plots and of carrying on the work for a few years only. The fundamental principles of the statistical method of analysis are based on large numbers of variables, for it is only when there are large numbers available that the laws of chance have a fair opportunity to operate. There are, however, several methods of analysis which have been evolved for relatively small numbers of variables. Even with these special methods there is always an element of danger in applying them rigidly when few individuals or varieties are involved. One of the special methods which possesses several advantages, and

which is meeting with considerable favor among agronomists, is that suggested by Student a number of years ago.* This method has been used in interpreting the results presented in this bulletin. The reader is referred to the literature cited for a discussion of the method, as illustrations of its use only will be presented here.

Suppose that it is desired to determine the significance of the difference in yield of bushels of shelled corn per acre between Leaming and Reid's Yellow Dent corn grown on the Agronomy Farm (Table III). We proceed as follows:

	1921	1922	1923	1924	
Yields of Leaming	45.9	71.3	59.8	41.9	
Yields of Reid's Yel. Dent	45.8	83.0	46.1	36.4	
Algebraic differences	+0.1	—11.7	+13.7	+5.5	
Mean difference					+1.9
Standard deviation of differences					∓9.2†

Divide the mean by the standard deviation, which gives the value of Z (1.9/9.2=0.21). Now looking up the odds in Love's tables (modified form of Student's table) corresponding to Z=0.21 and under n=4, we find by interpolation that they are approximately 1.7 to 1. In other words, the chances are only 1.7 to 1 that the difference between these two varieties is owing to an inherent difference in their yielding capacity for the particular conditions. From this we conclude that the difference in average yield between the two varieties in this experiment is not significant.

In a similar manner it is possible to determine the significance of the difference in yield in tons of air dry forage (Table V.) between Cocke's Prolific and Blue Ridge. Proceeding as before we find the odds are about 10 to 1. The chances are 10 to 1 that for the given conditions Cocke's Prolific possesses greater yielding capacity than Blue Ridge.

*See references to Student's Method in Literature Cited at end of this bulletin.

† In computing standard deviation the following formula was used: Standard deviation $= \sqrt{\frac{fd^2}{n}}$

LITERATURE CITED

LOVE, H. H., and BRUNSON, A. M.
1924. STUDENT'S METHOD FOR INTERPRETING PAIRED EXPERIMENTS. Jour. Amer. Soc. Agron. 16:60-68.

LOVE, H. H.
1924. A MODIFICATION OF STUDENT'S TABLE FOR USE IN INTERPRETING EXPERIMENTAL RESULTS. Jour. Amer. Soc. Agron. 16:68-73.

SALMON, S. C.
1924. SOME MISAPPLICATIONS AND LIMITATIONS IN USING STUDENT'S METHOD TO INTERPRET FIELD EXPERIMENTS. Jour. Amer. Soc. Agron. 16:717-721.

STUDENT
1908. THE PROBABLE ERROR OF A MEAN. Biometrika 6:1-12.

———
1915-17. TABLES FOR ESTIMATING PROBABILITIES BASED ON SMALL SAMPLES. Biometrika 11:414-417.

Bulletin 200

March, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Cultural Experiments with Wheat, Oats, and Buckwheat

Plots of Buckwheat Seeded at Different Rates on the Agronomy Farm, Morgantown, West Virginia.

By

T. E. ODLAND

Publications of this station will be mailed free to any citizen of West Virginia upon written application. Address Director of West Virginia Agricultural Experiment Station, Morgantown, West Viriginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
GEORGE R. LYMAN, Ph. D. .... Dean of the College of Agriculture
HENRY G. KNIGHT, Ph. D. .... Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
T. E. Odland, M. S. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, B. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assitsant Animal Husbandman
E. C. Stillwell, M. S. — Assitsant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

Henry G. Knight, Ph. D. — Chemist
R. B. Dustman, Ph. D. — Assistant Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
T. J. Cochran, B. S. — Junior Chemist

DAIRY HUSBANDRY

Ernest L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
Warren Gifford, B. S. Agr.†† — Junior Dairy Husbandman
G .M. Trout, M. S. — Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Junior Farm Economist
F. D. Cornell, M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D. — Home Economist

HORTICULTURE

M. J. Dorsey, Ph. D.*** — Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
Troy M. Currence, B. S. Agr.†† — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D. — Associate Soil Technologist

*In co-operation with the U. S. Department of Agriculture, Washington, D. C.
**In co-operation with the State Department of Agriculture, Charleston, W. Va.
***Resigned September 1, 1925.
‡In charge of the Maggie Sub-Station, Maggie, W. Va.
†In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††On leave of absence.

Cultural Experiments with Wheat, Oats, and Buckwheat

The three most important small grain crops grown in West Virginia are wheat, oats, and buckwheat. The average annual acreage of wheat is about 240,000 acres and of oats about 200,000 acres. The acreage of buckwheat grown averages about 40,000 acres annually. Two important considerations in connection with growing these crops are time and rate of seeding.

Experiments with different rates of seeding buckwheat and also seeding at different dates have been conducted previously at this station.* No such experiments had, however, been conducted with wheat and oats. It was therefore thought advisable to start a series of such experiments with these two latter crops and also to repeat certain portions of the buckwheat experiments. The results of these tests are reported in this bulletin.

METHODS OF EXPERIMENTATION

The different crops were seeded in plots consisting of strips one drill-width wide by approximately eight rods in length. Each rate and date of seeding was repeated four times each year except where otherwise noted. The drill used was a fourteen-hole single disc drill with discs seven inches apart. This made each plot about eight feet wide with an area of approximately one-fourtieth (1-40) of an acre.

An unseeded alley one and a half feet wide was left between plots. At harvest time the two outside drill rows of each plot were cut and discarded before the remainder of the plot was harvested. This was done in order to eliminate border effect. The drill was carefully calibrated each year for the different rates of seeding for each crop.

In computing the yields per acre the probable errors of the yields were also calculated. The probable error is used to determine how large a difference in yield between two series of plots should be before it is considered significant. When results from such experiments as reported in this bulletin are considered, the consistency of a difference in yield as well as the relative amount of such difference, should be taken into consideration. Since the probable error takes these factors into consideration it helps to determine what de-

*W. Va. Exp. Sta. Bul. 171, 1919.

gree of confidence one can place in the differences in yields obtained from various treatments. The method of computing probable errors based on the yield of varieties under test as described by Hayes was used.*

Table I shows the probable error in per cent for the different tests for each year, both for single plots and for the mean or average yield of the plots seeded at the same rate or date.

TABLE I.—The Probable Errors in Percentages for Date and Rate of Seeding Experiments as Measured by the Deviation of Each Plot from the Mean Yield of Each Treatment.

Crop	Number of Plots	Probable Error in Per Cent							
		1921		1922		1923		1924	
		Single Plot	Mean	Single Plot	Mean	Single Plot	Mean	Single Plot	Mean
Wheat (date seeding)	20*			5.3	2.7	10.0	5.0	7.8	3.9
Wheat (rate seeding)	20			11.3	5.7	6.6	3.0	6.3	2.8
Oats (rate seeding)	16†	4.2	2.4	14.2	7.1	6.7	3.4	8.6	4.3
Buckwheat (date seeding)	24	10.7	5.4	15.5	7.8	17.9	9.0	9.6	4.8
Buckwheat (rate seeding)	24‡	6.1	2.7	5.6	2.5	5.8	2.9	4.7	2.4

*25 plots in 1922 with 5 plots for each date.
†12 plots in 1921 with 3 plots in each rate.
‡25 plots in 1921-22 with 5 plots in each rate of seeding .

By applying the probable errors as shown in the table to the yield from different treatments, a figure is obtained showing the least difference in bushels that should be considered as a significant difference for each year of the experiment. It is interesting to note the variability shown in the probable errors for the different years and experiments. As an example the probable error for the buckwheat rate of seeding test is much smaller each year than for the date of seeding. This shows that the results from the rate of seeding experiment were much more uniform throughout than those from the date of seeding and, therefore, a much smaller difference in yield per acre could be considered significant.

Another method adopted to comparing average yields over a number of years was also used in determining the significance of the difference in average yields for the different treatments.† In this method the odds for or against a certain difference being significant are calculated.

*Hayes, H. K. Controllng Experimental Error in Nursery Trials. Jour. Amer. Soc. Agron. 15:177-192. 1923.
†Student. Probable Error of a Mean. Biometrika 6:1-25. 1908.

EXPERIMENTS WITH WHEAT

In the fall of 1921 a test with different rates and dates of planting winter wheat was started. Portage wheat was chosen as being typical of much of the winter wheat grown in this state. This variety is a beardless wheat of the soft winter wheat type. It is a selection from Poole wheat and has given very satisfactory results at the Ohio Station.

Date of Seeding

The date of seeding test consisted of plots seeded at ten-day intervals from September 10 to October 20. A uniform rate of six pecks per acre was used. Table II shows the yield per acre obtained over the three-year period.

TABLE II.—Yield of Winter Wheat Obtained at Different Dates of Seeding on the Agronomy Farm 1922-23-24.

Date of Seeding	Average Date Harvested	Yield in Bushels per Acre			Average Yield per Acre 1922-23-24
		1922	1923	1924	
September 20	July 6	29.5	30.1	33.7	31.1
September 30	July 7	29.4	33.1	26.2	29.6
September 10	July 3	27.7	27.1	30.1	28.3
October 10	July 10	23.7	22.5	18.2	21.5
October 20	July 11	19.2	12.1	14.1	15.1

In all three years the yields for wheat seeded October 20 were decidedly lower than from any of the earlier plantings. The odds as calculated are approximately 63 to 1 that the average yield obtained from the September 20 seeding is significantly higher than the average yield obtained from the October 20 seeding. Similarily the odds are 21 to 1 that the difference in yield obtained from the October 10 and October 20 seedings is significant. The October 10 seeding also produced lower yield than any seeded before this date. Apparently this date also is too late for conditions prevailing in this locality. These late seedings resulted in a large amount of winter killing.

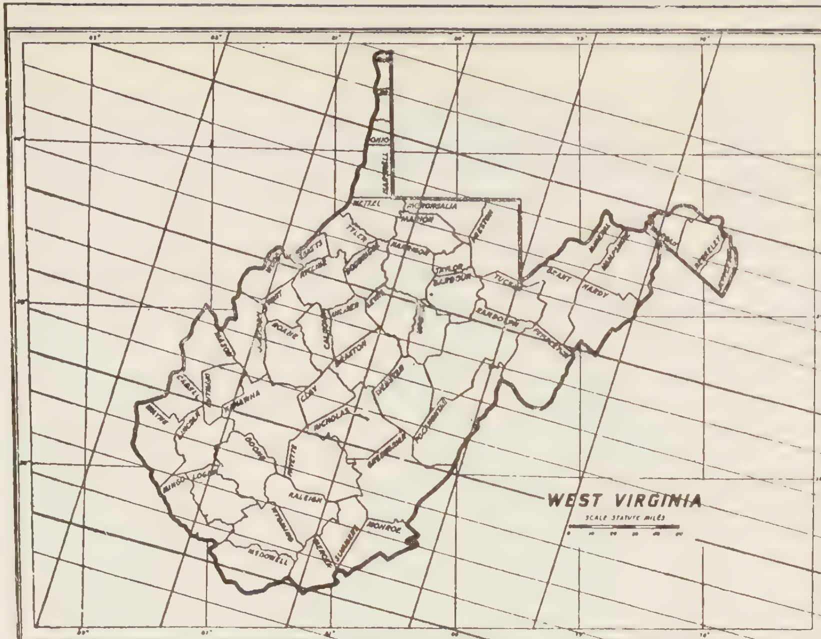
As an average for the three years there is little difference in yield in the three earlier plantings. In 1923 the September 30 seeding yielded more than the two seedings made prior to this date, but in 1924 it yielded less than these. The least difference in average yield that should be considered as significant as calculated from

Table I is approximately 3 bushels for 1922, 5.3 bushels for 1923, and 4 bushels for 1924.*

Winter wheat should not be sown too early on account of the danger of Hessian Fly infestation. The fall brood of this insect appears in August or the first part of September. If there is wheat growing at this time the eggs are deposited on the seedling plants where the young are hatched. These feed on the young wheat plants for a while in the fall and then go into the dormant stage. The chief injury is done when the spring brood appears.

If wheat is sown late enough to escape the fall brood there will be no flies to cause injury in the spring. The dates when wheat may safely be sown in a normal season so as to avoid the fall brood, have been faily well worked out. The accompanying chart and table shows the fly free dates for West Virginia for a normal season and for various altitudes.

*Average yield of all plots multiplied by $3\sqrt{2} \times$ RE. of mean.



400	800	1200	1600	2000	2400	2800	3200
	SEPT OCT	SEPT OCT					
	23 to 3	21 to 1					
	24 to 4	22 to 2					
			SEPT SEPT	SEPT SEPT	SEPT SEPT	SEPT SEPT	SEPT SEPT
	25 to 5	23 to 3	20 to 30	17 to 27	13 to 23	9 to 19	5 to 15
			OCT				
	26 to 6	24 to 4	21 to 1	18 to 28	14 to 24	10 to 20	6 to 16
	27 to 7	25 to 5	22 to 2	19 to 29	15 to 25	11 to 21	7 to 17
	28 to 8	26 to 6	23 to 3	20 to 30	16 to 26	12 to 22	8 to 18
OCT OCT				OCT			
1 to 11	29 to 9	27 to 7	24 to 4	21 to 1	17 to 27	13 to 23	9 to 19
2 to 12	30 to 10	28 to 8	25 to 5	22 to 2	18 to 28	14 to 24	10 to 20
	OCT						
3 to 13	1 to 11	29 to 9	26 to 6	23 to 3	19 to 29	15 to 25	11 to 21
4 to 14	2 to 12	30 to 10	27 to 7	24 to 4	20 to 30	16 to 26	12 to 22
		OCT			OCT		
5 to 15	3 to 13	1 to 11	28 to 8	25 to 5	21 to 1	17 to 27	13 to 23
6 to 16	4 to 14	2 to 12	29 to 9	26 to 6	22 to 2	18 to 28	14 to 24
7 to 17	5 to 15	3 to 13	30 to 10	27 to 7	23 to 3	19 to 29	15 to 25
			OCT				
8 to 18	6 to 16	4 to 14	1 to 11	28 to 8	24 to 4	20 to 30	16 to 26
						OCT	
9 to 19	7 to 17	5 to 15	2 to 12	29 to 9	25 to 5	21 to 1	17 to 27

ALTITUDE IN FEET ABOVE SEA LEVEL

Map of West Virginia Showing Safe Dates for Seeding Winter Wheat in a Normal Season at Different Altitudes. Seeding Before the Indicated Date Increases the Danger From Hessian Fly Infestation. (Courtesy U. S. Dept. of Agriculture.)

Dry weather may delay the emergence of the fly in the fall so that it might be necessary to seed later than the dates shown in the chart. It will be necessary to take the seasonal conditions into consideration each year in order to apply this chart properly. In looking at this chart we find that for the location of these experiments the dates recommended is from September 24 to October 4. The elevation of the Agronomy Farm is approximately 1200 feet. From the results obtained in the test it would seem that the fly free dates may be observed and still as high yields obtained as seeding at an earlier date. In 1924 a somewhat higher yield was obtained for the September 20 planting than the September 30, but in the other two years the September 30 seeding yielded as much or more than the earlier seedings. There was no fly infestation in any of the years of this experiment. It would not have been practical to conduct this test if fly infestation had been a common occurrence in this locality.

Plots of Winter Wheat Sown at Different Dates on the Agronomy Farm. The Thin Stands in the Center of the Picture Are of Plots Seeded October 10 and 20. On the Extreme Left the Plot Seeded September 10 is Shown.

Rate of Seeding

The rate of seeding wheat varied from four to eight pecks per acre. These plots were all seeded and harvested at the same time. The yields obtained are shown in Table III.

TABLE III.—Yields of Winter Wheat Obtained at Different Rates of Seeding on the Agronomy Farm 1922-23-24.

Rate of Seeding Pecks per Acre	Average Date of Seeding	Average Date of Harvest	Yield in Bushels per Acre			Average Yield per Acre
			1922	1923	1924	1922-23-24
8	Sept. 28	July 7	20.0	34.3	40.0	31.4
7	Sept. 28	July 7	16.0	34.7	37.7	29.5
6	Sept. 28	July 7	15.2	35.0	36.0	28.7
5	Sept. 28	July 7	13.9	33.5	34.1	27.2
4	Sept. 28	July 7	13.4	30.8	28.9	24.4

In 1922 the yields varied from 13.4 bushels per acre from the four-peck seeding to 20.0 bushels for the eight-peck rate with the other plots ranging between these in the order of the rate of seeding. Evidently for the conditions prevailing during that year a seeding of four or five pecks per acre was not enough. The yield from the six-peck seeding was 15.2 bushels per acre and from the seven-peck it was 16 bushels. The difference in yield between these two is not large enough to be considered significant.

In comparing rates of seeding yields the net yields should be used as the basis. The net yield of a plot is obtained by subtracting the amount of seed sown from the total yield. Thus the net yield from the six-peck seeding is 13.7 bushels, and from the eight-peck seeding it is 18 bushels. Considered in this way it can be stated with a fair degree of certainty that for this year seedings of seven and eight pecks per acre yielded better than the lighter seedings of four, five, and six pecks.

In the 1923 yields there is a lesser range between the different rates of seeding. The plots were located on better soil than in 1922 and the yields are all considerably higher. In this year the four-peck seeding again averaged the lowest yield with 30.8 bushels per acre. The six-peck seeding produced the highest average yield with 35.0 bushels. The seven and eight-peck seedings yielded 34.7 and 34.3 bushels per acre, respectively. The net yield per acre for all seedings were 29.8, 32.2, 33.5, 32.9, 32.3 bushels per acre for the four, five, six, seven, and eight-peck seedings, respectively. Under the more favorable soil and weather conditions prevailing this year there was little difference in yield between the different rates from five to eight pecks. The four-peck seeding was not enough to give the best results.

Plots in Rate of Seeding Wheat in Shocks With Cock Covers to Protect Against Birds and the Weather.

The season of 1924 was again favorable for wheat and the yields correspondingly high. The yields ranged from 28.9 bushels for the four-peck seeding to 40.0 bushels for the eight pecks. The net yields were 27.9, 32.8, 34.5, 35.9, and 38.0 bushels per acre for the four, five, six, seven, and eight-peck seedings, respectively. In this year as in 1922 the seven and eight-peck seedings yielded better than the lighter seedings. Four pecks again yielded considerably lower than the five or six-peck seeding.

The average net yields per acre for the three years were 23.4, 25.9, 27.2, 27.7, and 29.4 bushels per acre for the four, five, six, seven, and eight-peck seedings, respectively. From this it is seen that the eight-peck seeding averaged only 1.7 bushels more per acre than the seven-peck and the latter only .5 bushels more than the six-peck. Considering the short period over which the experiment extended these differences are probably not large enough to be of any significance. The odds are only 5 to 1 that the net yield obtained from the seeding of eight pecks per acre is significantly higher than that obtained from the seeding of six pecks per acre.

The five-peck seeding averaged 1.3 bushels less than the six-peck and the four-peck 2.5 bushels per acre less than the five-peck. The four-peck rate is too small while under favorable conditions the five-peck may give nearly as good results as six pecks or more. The odds are 18 to 1 that the net yield obtained from the eight-peck seeding is significantly higher than that obtained from the four-peck seeding. It seems that it is wiser to seed six pecks in order to be better insured against an adverse season. The increase in average yield for a seven or eight-peck seeding is not large enough, how-

ever, to warrant recommending a heavier seeding than six pecks per acre.

EXPERIMENTS WITH OATS

It is generally recognized that oats should be sown just as early in the spring as the ground can be put in shape. A date of seeding test was therefore not considered necessary for this crop. The rate of seeding test was started in the spring of 1921. The variety used the first year was Sweedish Select. This is a representative of the medium to late maturing oats. Iowa 103, an early maturing variety, was used in 1922, and Gopher oats, another early type, the following years. The results obtained over the four-year period are shown in Table IV.

TABLE IV.—Yields of Oats Obtained at Different Rates of Seeding on the Agronomy Farm 1921-24.

Rate of Seeding Pecks per Acre	Average Date of Seeding	Average Date of Harvest	Yield in Bushels per Acre				Average Yield per Acre 1921-24
			1921	1922	1923	1924	
12	April 10	July 18	26.8	15.3	40.3	42.3	31.2
10	April 10	July 18	29.7	15.2	36.5	40.9	30.6
8	April 10	July 18	30.9	13.9	35.1	39.0	29.7
6	April 10	July 18	24.5	14.5	33.9	35.1	27.0

In 1921 when Swedish Select oats were grown the eight and ten-peck rates of seeding yielded most. Six pecks were evidently not enough and the twelve-peck seeding did not yield as much as the intermediate rates. In 1922 the plots were located on rather thin soil and the season was not favorable for oats. As a result the yields were very low and fluctuated considerably. In this year the six-peck seeding yielded fully as well as any of the heavier seedings.

For the 1923 season there was a gradual increase in average yield from six-peck to twelve-peck seeding. The net yields per acre were 32.4, 33.1, 34.0, and 37.3 bushels for the six, eight, ten, and twelve-peck seedings, respectively. Here also the increase for the heavier seedings as compared with six pecks show only small increases in yield. The differences between six, eight, and ten pecks certainly are not large enough to be significant and it is doubtful whether even the net increase of the twelve-peck over the ten-peck seeding is large enough to be considered a real difference.

The net yields for 1924 were 33.6, 37.0, 38.4, and 39.3 bushels per acre for the six, eight, ten, and twelve-peck seedings, respectively.

In this year there was little difference in net yields between the eight, ten, and twelve-peck seedings. These, however, yielded better than the six-peck rate.

Considering the average yields for the different rates of seeding oats over the four year period, there is no appreciable difference in net yield for the eight, ten, and twelve-peck seedings. The six-peck seeding averaged approximately two bushels per acre less than the eight-peck seeding, and two and a half bushels less than the ten and twelve-peck seedings. Over the period under test, therefore, it would seem that eight pecks was a full seeding especially of early oats. There was no significant increase in yield from heavier seeding than this. A heavier seeding will do no harm and ordinarily a ten-peck seeding should probably be used in order to insure against adverse growing conditions.

EXPERIMENTS WITH BUCKWHEAT

Tests with different rates and dates of planting buckwheat were started in 1921. Japanese buckwheat was used in all these experiments. This variety is the one most commonly grown in West Virginia and has also consistently given the highest yields in the varietal experiments conducted at this station.

Date of Seeding

Buckwheat was planted at ten-day intervals from June 10 to July 30 each year. The field used in this experiment was plowed at the same time for all the plots, about May 15 to June 1. The ground was worked down to a good seedbed before the first planting was made. The plots seeded June 20 and later were given a double discing immedately before seeding in order to eradicate the weeds which usually appeared before that time. The plots were all seeded at the uniform rate of four pecks per acre.

TABLE V.—Yields of Buckwheat Obtained at Different Dates of Seeding on the Agronomy Farm 1921-24.

Date of Seeding	Average Date of Harvest	Yield in Bushels per Acre				Average Yield per Acre 1921-24
		1921	1922	1923	1924	
July 10	Sept. 20	21.7	16.7	14.9	19.3	18.2
July 20	Sept. 29	20.7	19.8	19.6	10.6	17.7
July 30	Oct. 5	8.1	14.5	23.0	15.0	15.2
June 10	Aug. 27	14.1	17.8	12.8	15.0	14.9
June 20	Sept. 5	16.6	14.1	10.2	18.1	14.8
June 30	Sept. 11	20.3	9.2	7.9	17.1	13.6

In 1921 the late seeding made July 30 produced the lowest yield with only 8.1 bushels per acre. The early plantings on June 10 and June 20 also produced relatively low yields. The intermediate dates of seeding June 30, July 10, and July 20 produced the highest yields with 20.3, 21.7, and 20.7 bushels per acre, respectively.

In 1922 the July 20 seeding made the best yield with 19.8 bushels and the June 30 seeding the lowest with 9.2 bushels per acre. The July 30 seeding made the highest yield in 1923 and the July 10 seeding in 1924. As an average of the four years the July 10 and 20 seedings, with 18.2 and 17.7 bushels respectively, yielded the most. The odds are 30 to 1 that the difference in average yield between the July 10 and the June 30 seedings is large enough to be considered a significant difference. The yields fluctuated considerably with the different dates of seeding for the different years. As an average for the conditions where this test was conducted, seeding some time from July 10 to 20 will probably give the most uniformly good results.

Rate of Seeding

The different rates of seeding buckwheat varied from two pecks to six pecks per acre in the first two years. A seeding of eight pecks per acre was also included in the last two years of this experiment. The plots were all seeded at the same time. Table VI shows the results obtained.

TABLE VI.—Yield of Buckwheat Obtained at Different Rates of Seeding on the Agronomy Farm 1921-24.

Rate of Seeding Pecks per Acre	Average Date of Seeding	Average Date of Harvest	Yield in Bushels per Acre				Average Yield per Acre 1921-24
			1921	1922	1923	1924	
2	July 9	Sept. 17	24.1	22.0	20.3	22.9	22.3
3	July 9	Sept. 17	22.7	21.6	21.3	23.7	22.3
4	July 9	Sept. 17	23.8	20.0	21.7	23.3	22.2
5	July 9	Sept. 17	23.6	18.9	23.1	23.2	22.2
8*	July 9	Sept. 17			22.3	21.5	21.9*
6	July 9	Sept. 17	22.1	17.0	24.5	22.5	21.5

*Two-year average.

It may be seen from Table VI that for the years under test there was not a very large difference in yield as a result of the different rates of seeding. As an average of the four years there was no significant difference in yield between any of the plots. The thin seeding of only two pecks per acre produced as high average yields as any of the heavier seedings. Where the net yields are considered

Plots of Buckwheat Sown at Different Dates on the Agronomy Farm.

the average yield from the two-peck seeding is 21.8 bushels per acre and for the six-peck 20 bushels.

Although in this test the two-peck seeding has proved as good as the heavier seedings, a seeding of three or four pecks probably should be recommended in order to insure a good stand under more adverse conditions. The heavy seedings of six and eight pecks per acre resulted in thin stemmed plants which did not stand up as well as the plants from the thinner seedings. This made these plots more difficult to harvest.

SUMMARY AND CONCLUSIONS

1.—Rate and date of seeding tests were conducted with wheat and buckwheat and a rate of seeding test was made with oats on the Agronomy Farm near Morgantown.

2.—Wheat seeded September 10 to 30 produced the highest yields. Wheat should not be seeded earlier than about September 25 in order to escape Hessian fly infestation.

3.—Seeding six pecks per acre is recommended for winter wheat.

4.—Eight or ten pecks per acre is recommended for early oats.

5.—Although two pecks per acre of buckwheat produced as high a yield as heavier seedings, a seeding of three or four pecks is recommended in order to insure against adverse conditions.

6.—Buckwheat seeded July 10 and 20 produced the best results.

Bulletin 201

April, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Some Factors Affecting the Weight of Eggs

(Technical)

By

HORACE ATWOOD

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
GEORGE R. LYMAN, Ph. D. .... Dean of the College of Agriculture
HENRY G. KNIGHT, Ph. D. .... Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
T. E. Odland, M. S. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, B. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
E. C. Stillwell, M. S. — Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

Henry G. Knight, Ph. D. — Chemist
R. B. Dustman, Ph. D. — Assistant Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
T. J. Cochran, B. S. — Junior Chemist

DAIRY HUSBANDRY

Ernest L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
Warren Gifford, B. S. Agr.†† — Junior Dairy Husbandman
G .M. Trout, M. S. — Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D. — Home Economist

HORTICULTURE

M. J. Dorsey, Ph. D.*** — Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
Troy M. Currence, B. S. Agr.†† — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D. — Associate Soil Technologist

---

*In co-operation with the U. S. Department of Agriculture, Washington, D. C.
**In co-operation with the State Department of Agriculture, Charleston, W. Va.
***Resigned September 1, 1925.
†In charge of the Maggie Sub-Station, Maggie, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††On leave of absence.

Some Factors Affecting the Weight of Eggs

Other things being equal, the food value of an egg is practically in direct proportion to its weight. Therefore, it is important to know the factors that tend to influence the size or weight of eggs. The size or weight of eggs is also of importance to the breeder since, other things being equal, the big egg hatches out the big lusty chick. Moreover, it is probably true that the same factors which bring about fluctuations in egg weight influence the number of eggs that a hen may lay, hence a knowledge of the causes which bring about variations in weight may be of value in throwing light on the process of egg production, and thus aid in the development of better methods of feeding and managing laying hens.

BRIEF REVIEW OF LITERATURE

It may be well to review briefly the observations and experiments which have been reported in experiment station publications with reference to egg weight.

Effect of Age of Laying Stock on Weight of Eggs

The age of the bird laying the egg has a marked influence on its weight. It is well known that pullet eggs are smaller than the eggs laid by mature fowls. Dryden (1900) found that the eggs laid by yearling White Leghorn hens averaged 8 per cent heavier than the eggs laid by the same birds during the pullet year. Hadley and Caldwell (1920) using White Plymouth Rocks found an average increase in the weight of the eggs of from 4 to 6 per cent from the first to the second laying season. Atwood (1925) with White Leghorns found an average increase from the first to the second laying season of about 11 per cent, and a further increase from the second to the third laying year of about 2 per cent. Lippincott (1921), Atwood (1923), and Jull (1924) found that the younger the pullets when beginning to lay the smaller were the first few eggs that were laid.

Weight of Eggs as Influenced by the Breed

The size of the egg is a breed characteristic. At one extreme stand the bantams with their small eggs and at the other are the Minorcas and Brahmas. Gilbert (1891) found that Barred Plymouth Rock and Black Minorca eggs average 1.69 pounds per dozen; Brah-

ma eggs 1.81 pounds; White Leghorn eggs 1.63 pounds; and Wyandotte eggs 1.56 pounds per dozen. Dryden (1899) gave the average weight of Light Brahma eggs at 1.64 pounds per dozen and Brown Leghorn eggs at 1.46 pounds. The same author in Bulletin 67 of the Utah Experiment Station gave the weight of White Leghorn eggs (mature fowls) at 1.56 pounds per dozen, White Leghorn pullets at 1.37 pounds, Wyandottes at 1.56 pounds, and Barred Plymouth Rocks at 1.52 pounds per dozen. Stewart and Atwood (1900) report the mean weight of eggs laid by mature White Leghorn hens at 1.43 pounds per dozen. Card and Kirkpatrick (1919) in summarizing the results obtained from five laying contests in which a large number of different pens participated found that the Plymouth Rock eggs averaged 1.56 pounds per dozen; the Wyandotte eggs 1.47 pounds; the Rhode Island Red eggs 1.57 pounds, and the White Leghorn eggs 1.51 pounds per dozen. The figures obtained from the laying contests probably fairly represent the weight of the eggs of the four principal breeds as they exist today, although it is probably true that certain strains of the same breed may differ as much as the breeds themselves.

Weight of Eggs as Influenced by the Ration

A ration that is not fed liberally enough reduces the size of the eggs. Atwood (1914) found that a ration fed too sparingly may reduce the general size of the eggs as much as 2.6 per cent; also that if a fowl is fed an improperly balanced ration the size of the eggs will be decreased. Additional data along this line are presented later in this publication.

The Effect of Confinement on Egg Weight

Gilbert (1891) found that the eggs laid by hens in confinement were not so large as those laid by the same hens when they had free range. Whether this result was due to the additional exercise or to some other factor is impossible to determine as Atwood (1922) in one case found the eggs larger and in another case slightly smaller as the result of confinement. The additional exercise resulting from running at large when taken in connection with a more perfectly balanced ration which frequently accompanies free range may be the means of increasing the egg weight.

Seasonal Variation in the Weight of Eggs

The seasonal distribution of egg weight with pullets is quite different from that of mature fowls. In the case of pullets under

normal conditions there is a constant and fairly uniform increase in egg weight from the beginning of the laying period, say in December or January, till the close of the laying year. This increase in egg weight is closely correlated with the increase in the body weight of the birds. In the case of mature fowls, however, the maximum mean egg weight is in December and January and the minimum is in June and July, the mean egg weight for any particular month being in inverse proportion to the number of eggs laid during that month. In other words, the more eggs laid by mature fowls during any particular period the smaller they tend to become for that period as shown by Atwood (1923).

Inheritance of Size of Eggs

Laurie (1912), Benjamin (1920), and others have found that the size of eggs does not appear to be sex limited. That is, either parent will transmit. In mating stock for egg production the tested hens selected should be layers of eggs of the size required, and should be the progeny of hens which laid eggs of similar size, and of cocks descended from hens which laid eggs of the desired size.

THE MEAN WEIGHT OF THE EGGS LAID BY BIRDS OF THE SAME VARIETY

In connection with experiments reported in bulletins 179 and 182 of this station the following data on egg weight have been obtained.

Fowls Employed

The fowls employed in this experiment were standard bred Single Comb White Leghorns. Prior to the beginning of this experiment this strain of fowls had not been trapped or bred for egg production. From the standpoint of the weight of eggs these fowls may be considered as a random sample of Single Comb White Leghorns. Each female in flock A had one or more full sisters in flock B and vice versa. Likewise the birds in flocks C and D were sisters and E. and F were sisters. Flocks A, C, and E were well fed while young; flocks B, D, and F were fed rations low in protein and ash so that the increase in live weight was slow. After laying began all six flocks were fed uniformly on a well balanced laying ration.

The data used in this discussion cover three years' of production for flocks A and B, two years' for flocks C and D, and one year's production for flocks E and F. The laying year in all cases began December 1 and ended November 30. All eggs were weighed early each morning on the day following that on which they were laid, and in this discussion double yolked eggs and those abnormally small were disregarded. Most of the eggs were weighed on a chainomatic balance and the weights were recorded to one one-hundredth gram.

Tables 1, 2, 3, 4, and 5 show the number and the mean weight of the eggs laid by each bird. These tables are summarized and combined in Tables 6, 7, 8, and 9.

TABLE 1.—Number and Mean Weight of Eggs; Flock A, Well Fed While Young.

Band No. of Bird	FIRST YEAR		SECOND YEAR		THIRD YEAR	
	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs
301	146	49.38±.20	178	54.38±.14	148	55.29±.12
302	187	51.77±.17	192	58.13±.10	184	58.01±.12
308	56	49.38±.19	164	53.64±.12	123	54.70±.14
309	184	50.64±.18	133	58.03±.14	115	59.09±.20
311	180	50.68±.19	165	59.71±.11	145	59.57±.12
313	166	52.08±.18	176	56.72±.17	84	58.37±.13
315	164	52.73±.25	197	57.08±.11	146	56.23±.19
320	118	46.48±.17	103	52.29±.17	82	54.77±.26
322	165	50.69±.15	156	57.92±.13	152	58.01±.13
324	156	49.45±.14	135	55.21±.13	122	56.33±.11
325	162	49.03±.17	144	57.40±.14	140	58.59±.14
326	132	53.10±.19	142	56.21±.24	140	57.34±.18
327	149	53.91±.34	166	57.20±.17	168	57.29±.13
330	84	49.49±.24	153	55.97±.12	133	56.49±.17
331	165	51.39±.15	108	57.14±.11	135	56.93±.12
332	177	52.50±.26	140	59.52±.15	145	59.27±.13
333	140	49.55±.17	98	54.85±.22	111	54.77±.18
336	122	46.08±.18	134	51.46±.12	129	51.33±.22
342	169	49.98±.13	164	56.70±.13	137	58.19±.18
347	130	49.25±.24	133	54.45±.17	159	54.73±.14
351	109	48.56±.21	171	53.23±.16	151	52.44±.20
355	170	50.19±.18	179	58.77±.16	162	59.58±.21
356	150	46.17±.26	158	49.49±.13	167	50.96±.13

TABLE 2.—Number and Mean Weight of Eggs; Flock B, Poorly Fed While Young.

Band No. of Bird	FIRST YEAR		SECOND YEAR		THIRD YEAR	
	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs
303	94	50.78±.22	155	55.67±.21	117	54.74±.20
304	112	42.27±.18	158	48.91±.13	105	50.14±.17
305	180	48.95±.15	132	54.51±.14	133	55.05±.14
306	187	57.18±.27	156	64.65±.17	85	64.36±.28
312	83	52.50±.20	93	57.89±.26	80	58.00±.26
314	140	51.94±.20	133	59.45±.10	119	58.70±.11
316	138	51.54±.25	180	56.25±.13	163	56.35±.16
319	163	50.00±.23	162	54.15±.12	144	55.50±.15
323	183	48.66±.20	181	55.13±.13	144	54.51±.15
329	100	53.43±.16	141	60.88±.14	124	62.76±.20
334	126	49.94±.14	146	53.47±.15	151	52.68±.13
335	111	52.46±.17	166	60.14±.14	144	59.97±.16
337	97	52.30±.38	137	54.70±.17	144	55.99±.16
338	93	48.24±.16	134	51.61±.14	148	52.35±.13
340	74	49.95±.20	154	54.96±.18	153	55.23±.16
341	106	50.78±.25	177	56.09±.15	156	56.52±.15
345	132	53.16±.18	171	59.12±.12	144	59.97±.12
348	78	51.74±.24	135	57.16±.14	72	57.19±.18
350	72	48.81±.28	132	52.52±.15	150	55.37±.16
352	135	47.59±.18	152	52.47±.14	109	52.12±.13
354	143	51.68±.15	156	55.31±.14	135	56.03±.17

TABLE 3.—Number and Weight of Eggs; Flock C, Well Fed While Young.

Band No. of Bird	FIRST YEAR		SECOND YEAR	
	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs
401	148	48.28±.24	143	53.98±.15
402	149	52.51±.22	162	59.52±.16
403	123	53.02±.25	155	60.07±.15
404	111	51.20±.22	148	56.40±.15
406	108	49.55±.21	145	53.23±.13
407	125	50.54±.22	153	57.43±.13
409	156	52.70±.30	133	60.73±.18
411	108	52.37±.30	151	57.24±.14
415	134	45.75±.17	129	51.47±.15
419	150	50.16±.14	156	54.53±.15
420	155	52.93±.18	122	57.58±.15
421	150	48.12±.13	154	52.05±.10
422	82	52.26±.24	89	56.30±.19
424	203	51.82±.23	173	58.98±.13
428	124	52.53±.17	172	59.62±.16
431	133	51.51±.20	152	56.92±.13
432	143	52.77±.17	158	60.84±.18
434	147	50.30±.14	114	53.30±.16
435	208	52.94±.19	179	57.54±.12

TABLE 4.—Number and Mean Weight of Eggs; Flock D, Poorly Fed While Young.

Band No. of Bird	FIRST YEAR		SECOND YEAR	
	Number of Eggs Laid	Mean Weight of Eggs	Number of Eggs Laid	Mean Weight of Eggs
405	97	50.74±.26	132	56.79±.20
408	135	46.69±.25	120	51.75±.23
410	136	58.85±.20	139	64.40±.20
413	107	49.54±.28	84	54.14±.15
416	112	50.54±.16	159	53.30±.12
418	140	48.65±.15	164	55.09±.11
423	125	49.82±.23	124	53.22±.15
425	157	50.21±.19	109	54.84±.23
426	110	48.69±.20	182	53.13±.12
427	168	48.76±.16	168	52.79±.12
429	79	52.09±.16	144	55.31±.14
436	158	50.95±.17	214	52.34±.15
437	125	51.16±.27	129	53.88±.18
438	140	50.76±.18	120	54.44±.12
439	186	50.73±.14	141	55.44±.13
440	112	50.84±.21	121	55.33±.21
441	119	47.25±.19	158	50.80±.13
442	120	52.88±.21	155	58.26±.17
443	60	47.43±.40	139	48.76±.18

TABLE 5.—Flocks E and F; Pullet Year; Flock E, Well Fed While Young; Flock F, Poorly Fed while Young.

Band No. of Bird	FLOCK E Number of Eggs Laid	FLOCK E Mean Weight of Eggs	Band No. of Bird	FLOCK F Number of Eggs Laid	FLOCK F Mean Weight of Eggs
500	150	51.52±.14	550	170	49.72±.20
501	129	50.43±.17	551	139	55.47±.17
502	148	51.49±.15	552	160	52.92±.15
503	134	54.23±.10	553	138	54.15±.16
504	174	53.25±.16	554	70	51.46±.12
506	188	54.45±.18	555	149	52.65±.20
507	180	52.74±.14	557	113	53.22±.17
508	98	54.76±.20	558	185	49.10±.12
510	118	52.68±.19	559	181	51.19±.17
511	147	52.83±.15	560	145	53.99±.18
512	99	49.94±.22	561	153	54.17±.12
513	158	48.37±.15	562	127	52.48±.12
514	186	50.13±.17	563	172	53.32±.15
515	166	52.35±.14	565	174	57.63±.14
516	132	50.63±.11	566	153	54.66±.17
517	167	53.73±.17	567	70	45.13±.35
518	138	54.02±.15	568	200	53.68±.12
519	193	48.81±.11	569	140	55.99±.16
520	183	50.06±.14	570	145	52.99±.10
521	167	50.57±.13	571	151	46.42±.11
522	176	49.06±.10	572	132	54.84±.14
523	172	53.70±.18	573	101	47.90±.25
524	165	54.43±.17	574	107	57.08±.16
525	108	52.53±.14	575	141	55.38±.13
526	174	51.10±.15	576	121	49.42±.15
527	182	50.47±.18	577	145	52.80±.18
528	152	56.39±.14	578	154	48.62±.18
529	189	51.07±.13	579	160	50.31±.18
530	186	48.41±.13	580	125	51.50±.14
532	137	47.49±.21	581	142	46.54±.15
533	121	53.34±.13	582	76	50.49±.25
534	159	51.35±.17	584	145	48.41±.14
535	182	51.92±.16	585	123	53.76±.18
536	171	50.42±.13	586	176	49.49±.16
537	143	55.43±.16	587	146	55.21±.17
538	160	53.86±.22	588	130	51.25±.18
539	139	49.02±.21	589	155	50.49±.14
540	164	50.68±.22	590	147	50.49±.16
541	148	52.18±.12	591	165	50.42±.15
542	160	50.49±.18	592	126	52.77±.19
543	178	52.11±.14	593	105	47.28±.16
544	115	48.34±.26	594	183	45.73±.11
545	157	53.76±.14	595	121	51.80±.15
546	174	50.54±.10	596	137	56.12±.16
547	149	48.50±.20	597	179	50.56±.16
548	165	51.79±.15	598	109	48.75±.19
549	155	51.77±.13	599	53	50.46±.28
			600	40	57.40±.33

TABLE 6.—Summary of Results With Hens Well Fed While Young.

Flocks	Year	Number of Fowls	Mean Number of Eggs	Mean Annual Weight of Eggs	Standard Deviation in Number of Eggs	Standard Deviation in Mean Annual Egg Weights	Mean Standard Deviation in Weight of Eggs
A	First	23	147.00±4.47	50.12±.29	31.8±3.16	2.04±.20	3.53±.13
A	Second	23	151.69±3.65	55.90±.36	26.0±2.58	2.54±.25	2.61±.08
A	Third	23	138.17±3.40	56.47±.35	24.2±2.41	2.46±.25	2.72±.05
C	First	19	140.00±4.58	51.12±.30	29.6±3.23	1.95±.21	3.57±.13
C	Second	19	146.68±3.28	56.72±.44	21.2±2.32	2.83±.31	2.63±.05
E	First	47	155.75±2.34	51.67±.20	23.8±1.65	2.04±.14	3.00±.06

TABLE 7.—Summary of Results with Hens Poorly Fed While Young.

Flocks	Year	Number of Fowls	Mean Number of Eggs	Mean Annual Weight of Eggs	Standard Deviation in Number of Eggs	Standard Deviation in Mean Annual Egg Weights	Mean Standard Deviation in Weight of Eggs
B	First	21	121.29±5.15	50.62±.42	35.0±3.64	2.84±.30	3.37±.13
B	Second	21	150.05±2.97	55.97±.51	20.2±2.06	3.47±.36	2.69±.07
B	Third	21	129.52±3.77	56.36±.50	25.6±2.66	3.38±.35	2.73±.07
D	First	19	125.06±4.87	50.35±.40	31.5±3.44	2.56±.28	3.41±.10
D	Second	19	142.21±4.36	53.89±.51	28.2±3.08	3.28±.36	2.74±.12
F	First	48	137.40±3.33	51.76±.30	34.2±2.35	3.12±.21	2.80±.05

Table 8.—Summary of Results With Hens Well Fed While Young; Flocks Combined by Years.

Flocks	Year	Number of Fowls	Mean Number of Eggs	Mean Annual Weight of Eggs	Standard Deviation in Number of Eggs	Standard Deviation in Mean Annual Egg Weights	Mean Standard Deviation in Weight of Eggs
A. C, E	First	89	150.12±2.00	51.15±.15	28.1±1.42	2.12±.11	3.26±.06
A. C.	Second	42	149.43±2.51	56.27±.28	24.1±1.77	2.71±.20	2.62±.05
A	Third	23	138.17±3.40	56.47±.35	24.2±2.41	2.46±.25	2.72±.05

TABLE 9.—Summary of Results With Hens Poorly Fed While Young; Flocks Combined by Years.

Flocks	Year	Number of Fowls	Mean Number of Eggs	Mean Annual Weight of Eggs	Standard Deviation in Number of Eggs	Standard Deviation in Mean Annual Egg Weights	Mean Standard Deviation in Weight of Eggs
B, D, F,	First	88	131.00±2.47	51.19±.22	34.4±1.75	3.01±.15	3.07±.05
B, D	Second	40	146.33±2.62	54.98±.38	24.6±1.86	3.54±.27	2.74±.05
B	Third	21	129.52±3.77	56.36±.50	25.6±2.66	3.38±.35	2.73±.07

The number and the mean weight of the eggs laid by the birds in flocks A and B for the first two years and by the birds in flocks C and D for the pullet year have already been considered in Bulletin 179 of this station. For the purpose of presenting a comprehensive survey of the experiment these data are included and the results are here discussed as a whole.

Number of Eggs Laid

Tables 1 to 9 record only the eggs gathered from the trap nests. Double-yolked eggs and those abnormally small have been disregarded. The actual number of eggs laid by these fowls was between 2 and 3 per cent greater than is shown in the tables, but it is believed that this source of error would have little or no effect upon the mean egg weights or upon the standard deviation as shown in Tables 6, 7, 8, and 9.

During the pullet year the egg production varied from a minimum of 40 eggs laid by bird No. 600 to 208 eggs laid by bird No. 435.

The mean egg production for the pullet year of the birds which were well fed while young was 150.12±2.00 while their poorly fed sisters laid only 131.00±2.47 eggs or a difference of roughly one and one-half dozen eggs per bird. In this connection it should be remembered that after laying began all these birds were fed and handled in exactly the same way. After the first year there was practically no significant difference in the egg production of the two lots of sisters.

Weight of Eggs

In the pullets the mean egg weight varied from a minimum of 42.27±.18 grams (bird 304) to a maximum of 58.85±.20 grams (bird 410) thus giving a difference of 16.58±.27 grams. This difference in mean egg weight is so large that five of the eggs laid by bird 410 would weigh practically the same as seven laid by 304. This is an illustration of the desirability, if not the necessity of selecting and breeding for greater uniformity in egg weight.

Of the 177 fowls there were only seven, Nos. 306, 410, 528, 565, 574, 596, and 600 whose pullet eggs averaged 56 grams or more, and as it is desirable to produce a two-ounce egg selection should be exercised in this strain to increase the mean egg weight. This should not be difficult to accomplish as Atwood (1925) has shown that there is a positive correlation between mean egg weight and mean body weight, hence by disposing of the smaller pullets each fall the egg size would be gradually increased even though no effort were made to breed from the birds laying the larger eggs.

After the first year the eggs were practically of standard weight although those laid by flocks B and D during the second year were a trifle too small.

The mean weight of the pullet eggs laid in this experiment was 51.17±.13 grams; for the second year, 55.62±.23 grams, and 56.41±30 grams for the third year of production. The increase in the weight of the eggs the second year as compared with the first was 4.45±.26 grams; and the increase for the third year as compared with the second was .79±.38 grams. It is evident, therefore, that the eggs attained almost their full weight during the second year of production. Apparently, the different rations fed the growing chickens had no effect upon the weight of the eggs laid.

Standard Deviation in Number and Weight of Eggs

The standard deviation in the number of eggs laid was largest during the pullet year. Comparing the deviations in number of eggs laid by flocks A, C, and E with the deviations for flocks B, D, and F it is seen that these deviations average larger for the latter flocks. In other words, the poor ration fed to the females in flocks B, D, and F seems to have increased variability in respect to the number of eggs laid.

Similarly, too, the standard deviation in the mean annual weight of the eggs was greater in the case of flocks B, D, and F indicating that the poor ration fed to these fowls while young caused them to become somewhat more variable in respect to their mean annual egg weight.

The standard deviation in the weight of the eggs was largest during the pullet year. No significant difference can be observed in the standard deviation in the weight of the eggs resulting from the rations fed the growing chickens.

The mean standard deviation in the weight of White Leghorn eggs, based on 303 annual records of production, namely, 177 annual pullet records, 82 annual yearling hen records, and 44 two-year-old hen records, was 2.97±.03 grams, with a maximum deviation of 6.14±.24 grams and a minimum deviation of 1.52±.09 grams or a variation about four times as great as the minimum deviation.

The mean weight of all of the eggs laid in this experiment based on the means derived from the 303 annual records was 53.14±.14 grams, and the standard deviation of the 303 mean annual egg weights was 3.68±.10 grams.

An inspection of the tables shows that the deviation in the mean annual egg weights for the various females is slightly greater than the deviation in the weight of the individual eggs laid by them.

Uniformity of Mean Egg Weight in Individual Birds

Although the weight of the eggs laid by the same bird fluctuates from day to day and from month to month yet each individual has a characteristic egg weight that remains fairly uniform except that it increases with the age of the bird, and especially during the pullet year. Table 10 shows the correlation between the mean egg weight for the pullet year and the mean egg weight for the second year of production based, on the 82 records which are complete for the two years. Table 11 presents the data for the 44 fowls whose records were complete for the three years.

TABLE 10.—Scatter Diagram of Mean Egg Weights of 82 Fowls for the Pullet Year and the Second Year of Production.

Flocks A, B, C, D Pullets Grams	Flocks A, B, C, D, Yearlings—Grams																	
	48.5	49.5	50.5	51.5	52.5	53.5	54.5	55.5	56.5	57.5	58.5	59.5	60.5	61.5	62.5	63.5	64.5	Total
42.5	1																	1
43.5																		
44.5																		
45.5				1														1
46.5		1		2	1													4
47.5	1		1		1													3
48.5				1	3	3	1	2										10
49.5						4	5	2	1	1								13
50.5					1	2	4	3	2	2	2	1						17
51.5						1		1	3	2	2	1						10
52.5							1	1	2	5	1	3	3					16
53.5									1	1		1	2					5
54.5																		
55.5																		
56.5																		
57.5																	1	1
58.5																	1	1
Total	2	1	1	4	6	10	11	9	9	11	5	6	5				2	82

$r = +.86 \pm .02$

TABLE 11.—Scatter Diagram of Mean Egg Weights of 44 Fowls for the Second and Third Years of Production.

Flocks A and B Second Year Grams	Flocks A and B Third Year—Grams															
	50.5	51.5	52.5	53.5	54.5	55.5	56.5	57.5	58.5	59.5	60.5	61.5	62.5	63.5	64.5	Total
48.5	1															1
49.5	1															1
50.5																
51.5		1	1													2
52.5			1		1	1										3
53.5			2		1											3
54.5					2	5										7
55.5					2		2	1								5
56.5							2	1	2							5
57.5							2	2	3							7
58.5									1	2						3
59.5									1	3						4
60.5										1			1			2
61.5																
62.5																
63.5																
64.5															1	1
Total	2	1	4		6	6	6	4	7	6			1		1	44

$r = +.95 \pm .01$

The coefficient of correlation between the mean annual weight of the eggs laid during the first and second years by the 82 fowls with a record for two years was $+.86 \pm .02$; and for the second and third years for the 44 fowls that had a record for three years was $+.95 \pm .01$. This shows a very high correlation of the mean annual egg weight from one year to another, and it may be stated that the average size of the eggs laid by a hen is a very fixed, definite, and persistent characteristic. On the other hand the coefficient of corre-

lation between the standard deviations in the weight of the eggs of the same fowls for the first and second years was $+.21\pm.07$ and for the second and third years was $+.44\pm.08$. In other words the standard deviation in egg weight for any female is a less permanent or persistent character than is the mean egg weight.

THE INFLUENCE OF DIFFERENT RATIONS ON EGG WEIGHT

In order to determine whether the character of the ration fed to laying hens has any appreciable influence on the weight of the eggs laid, and whether the ration that will produce the largest number of eggs will produce eggs of greatest average weight the experiment herein described has been carried out.

This experiment was started November 1, 1923, with six pens of Single Comb White Leghorn pullets hatched May 9, 1923. Each pen contained sixteen birds and the pens were numbered 4 to 9, inclusive.

During November and December scratch feed and laying mash were fed to all pens alike but during the next four months or until May 1, pens 4, 6, and 7 received whole grain only, the laying mash being withheld. After May 1 all six pens were fed alike, laying mash being provided in hoppers and scratch grain fed in straw litter. The scratch feed consisted of 2 parts corn, 2 parts wheat, and 1 part oats. The mash consisted either of Full-o-pep laying mash or a mixture of 2 parts corn meal and 1 part each of wheat bran, red dog, and meat scrap.

Table 12 gives the number and mean weight of eggs laid by each pen during the first year of the test.

TABLE 12.—Number and Mean Weight of Eggs Laid by the Six Pens of White Leghorns During the First Year of the Experiment.

Months and Items Considered	Pen 4		Pen 5		Pen 6		Pen 7		Pen 8		Pen 9	
	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams
November 1923	113		160		86		124		87		161	
December 1923	103		137		65		32		106		153	
January 1924	5		66		23		11		49		58	
February 1924	64		168		56		55		178		184	
March 1924	141	50.32	324	56.36	136	48.54	152	47.59	326	55.15	361	55.00
April 1924	110	49.36	382	55.80	65	47.83	84	46.47	337	54.54	390	54.09
May 1924	315	54.15	348	54.90	258	51.12	269	49.62	341	53.86	395	52.61
June 1924	361	54.57	276	54.75	353	52.53	322	50.98	328	53.46	365	52.29
July 1924	331	54.31	238	54.47	307	52.74	302	50.95	284	53.41	355	52.90
August 1924	294	54.23	187	54.89	292	52.66	260	51.28	208	55.00	239	53.70
September 1924	211	55.47	105	55.37	188	54.43	167	52.49	94	56.22	105	55.30
October 1924	85	56.54	23	56.91	53	56.87	70	54 81	49	56.51	56	54.29
Unweighted mean weight for March and April		49.84		56.08		48.19		47.03		54.85		54.55
Unweighted mean weight for May and June		54.36		54.83		51.83		50.30		53.66		52.45
Gain or loss as compared with March and April		4.52 Gain		1.25 Loss		3.64 Gain		3.27 Gain		1.19 Loss		2.10 Loss

The unweighted mean weight of the eggs laid by pens 4, 6, and 7 for the months of March and April was 48.35 grams, while the unweighted mean weight of the eggs laid by the other pens was 55.17 grams, or a difference in weight due to feeding the unbalanced ration of 6.81 grams or slightly more than 12 per cent. During the next two months when pens 4, 6, and 7 were fed mash the mean weight of the eggs increased 3.81 grams while the eggs from pens 5, 8, and 9 decreased 1.52 grams. This decrease in weight, however, was entirely normal and to be expected as eggs usually are smaller during the summer months.

Withholding the mash from pens 4, 6, and 7 until after May 1 had the effect of holding up the average egg weight after May 1 when under normal feeding it would have fallen. As the heavy egg produces the heavy chick this procedure may be of practical importance whenever it is desirable to produce eggs for hatching late in the season.

Second Year of Test

The experiment was continued during the second year with the same fowls and on the same plan except that pens 5, 8, and 9 were the ones which received no mash during January, February, March and April. Table 13 shows the number and mean weight of the eggs by months.

The results for the second year are in entire agreement with those obtained during the first year, in that the feeding of the ration consisting of whole grain reduced the number and mean weight of the eggs. Later in the season when mash was fed the weight of the eggs laid by these fowls increased while the weight of the eggs laid by the comparative lots decreased. It is consequently evident that the size of the eggs depends to a certain extent upon the character of the ration provided for the layers.

TABLE 13.—Number and Mean Weight of Eggs Laid by the Six Pens of White Leghorns During the Second Year of the Experiment.

Months and Items Considered	Pen 4		Pen 5		Pen 6		Pen 7		Pen 8		Pen 9	
	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams	Eggs Laid	Mean Weight Grams
November, 1924	28	59.93	30	59.67	19	57.37	16	54.05	21	58.71	26	58.35
December, 1924	8	58.00	4	60.50	24	57.29	12	56.75			7	55.43
January, 1925	43	60.65	6	60.67	23	57.52	26	55.62	2	54.50	7	52.29
February, 1925	81	60.28	33	56.52	96	56.47	59	55.42	36	54.53	42	55.57
March, 1925	189	57.86	69	54.39	298	57.26	176	55.64	82	54.38	121	55.37
April, 1925	352	57.49	115	52.26	342	56.08	311	54.45	152	53.14	232	53.69
May, 1925	343	56.94	235	55.44	351	55.83	338	54.22	289	54.51	307	54.61
June, 1925	310	55.43	278	54.40	345	54.35	303	53.06	320	54.12	343	54.47
July, 1925	310	55.63	193	54.43	340	54.31	323	53.29	307	54.39	321	55.34
August, 1925	261	56.08	163	54.67	274	54.62	275	54.06	265	55.14	211	55.87
Unweighted mean weight for March and April		57.68		53.33		56.67		55.05		53.76		54.53
Unweighted mean weight for May and June		56.18		54.92		55.09		53.64		54.31		54.54
Gain or loss as compared with March and April		1.40 Loss		1.59 Gain		1.58 Loss		2.41 Loss		.55 Gain		.01 Gain

A COMPARISON OF THE WEIGHTS OF THE EGGS IN A CYCLE, WITH REFERENCE TO NUMERICAL PRODUCTION

When a bird lays without interruption for two or more days in succession and then ceases to lay for one or more days, the eggs thus laid in succession are termed a cycle.

It has been pointed out by Curtis (1914) and also by Atwood and Weakley (1917) that as a rule the eggs in a cycle decrease in weight from the first egg toward the last egg of the series, the next cycle beginning with a heavy egg and so on. This general rule is illustrated by Table 14 which gives the date of laying and the weight of the eggs laid by Bird 322 for May, 1923.

TABLE 14.—Record of Eggs Laid by Bird No. 322 for May, 1923.

Day of Month	Weight of Egg in Grams	Day of Month	Weight of Egg in Grams	Day of Month	Weight of Egg in Grams
1	61.28	11	56.85	21	57.42
2	59.16	12	57.35	22	56.92
3	57.34	13	58.52	23	55.68
4	57.42	14	none	24	none
5	54.37	15	61.71	25	59.10
6	59.97	16	59.13	26	57.71
7	57.78	17	59.60	27	55.68
8	58.78	18	60.13	28	56.45
9	none	19	none	29	none
10	61.93	20	59.02	30	60.66
				31	58.50

It is to be observed that there is not a perfectly regular decrease in egg weight from day to day. In the first cycle the egg laid on May 6 was heavier than the egg laid May 2, and there were only three eggs which were larger than the last egg of the cycle. In the next cycle the eggs laid on the 12 and 13 were each heavier than the egg laid on the 11. In the cycle beginning May 20, each egg in the series is smaller than the egg which immediately precedes it, thus agreeing with the general rule, but the decrease in weight varies considerably being 1.60, .50, and 1.24 grams per egg. It is therefore evident that in these cycles there is no great amount of regularity in the decrease in egg weight from day to day. In fact, other instances could be easily cited in which the egg weight is much more variable than in the case given. Nevertheless, when a sufficiently large number of records is examined, the truth of the general law that there is a progressive decrease in the weight of the eggs in a cycle becomes clearly evident.

In Table 14 there are six cycles. The average decrease in the weight of the eggs in a cycle may be calculated from the formula $\frac{A-L}{N-1}$ in which "A" represents the weight of the first egg of the series "L" the weight of the last egg and "N" the number of eggs. For example, in the first cycle, the mean decrease is .357 grams. The mean decrease for a number of cycles may be calculated by the formula $\frac{\Sigma\,(A-L)}{\Sigma\,(N-1)}$. Making the necessary calculations for the six cycles in Table 14 one finds $\frac{\Sigma\,(A-L)}{\Sigma\,(N-1)} = \frac{15.64}{20}$ or a mean decrease of .782 grams per egg.

Fowls Employed

The fowls whose eggs were used in this work were single comb White Leghorns. They were in flocks A, B, C, D, E, and F, to which reference has already been made in this bulletin. For the purposes of this study they may be considered as a random sample of White Leghorns.

Table 15 gives the number of birds whose records are included for each month; the mean decrease in the weight of the eggs in the cycles; the mean number of eggs laid per month; and the coefficient of correlation between the mean decrease per egg and the number of eggs laid per month for the birds in flocks A and B during their third laying year.

Table 15 shows that the mean decrease in the weight of the eggs in the cycles ranged from a maximum of 2.828 grams in October to a minimum of 1.430 grams in May.

The coefficients of correlation with the exception of that for February, are all negative and they are significant for the months of June, August, September, and October. On account of the fact that in October there were only six hens with enough cycles so that their records could be used, too much stress should not be laid on the relatively high correlation for that month.

The coefficients of correlation indicate that the greater the rate of egg production, the smaller is the decrease in the weight of the eggs in the cycles.

Table 16 derived from Table 15 shows the mean decrease in the weight of the eggs in the cycles, the mean number of eggs produced each month and the percentage daily egg production per month for flocks A and B during their third laying season.

TABLE 15.—Number of Eggs Laid; the Mean Decrease in Their Weight; and the Correlation Between Number of Eggs Laid and Mean Decrease in Weight for Flocks A and B During Nine Months of Their Third Laying Year.

Items Considered	February	March	April	May	June	July	August	September	October
Number of birds included	24	43	44	44	41	41	37	30	6
Mean decrease in weight per egg—grams	2.559	2.111	1.453	1.430	1.631	1.446	1.874	2.218	2.828
Mean number of eggs laid per month	8.87	18.80	20.43	20.73	18.46	20.32	19.16	14.96	14.16
Correlation between decrease in weight per egg and number of eggs laid. r=	+.120±.135	—.215±.098	—.051±.101	—.229±.096	—.424±.086	—.287±.097	—.430±.090	—.423±.101	—.821±.090

TABLE 16.—Mean Decrease in Weight of Eggs in Cycles, Mean Number of Eggs per Month, and Percentage Daily Production per Month for Flocks A and B during Third Laying Season.

Months	Mean Decrease in Weight of Eggs in Cycles; Grams	Mean Number of Eggs Laid per Bird per Month	Per Cent Daily* Production
February	2.56	8.87	31.7
March	2.11	18.80	60.6
April	1.45	20.43	68.1
May	1.43	20.73	66.9
June	1.63	18.46	61.5
July	1.45	20.32	65.5
August	1.87	19.16	61.8
September	2.22	14.96	49.9
October	2.83	14.16	45.7

*Obtained by dividing the mean number of eggs laid per month, by the number of days in that month, and then multiplying the quotient by 100.

The unweighted mean decrease in the weight of the eggs during the nine months was 1.950 grams. The correlation between the decrease in weight and the per cent daily egg production was, $r = -.873 \pm .053$. Consequently, it is plainly evident that there is a relatively high degree of relationship between the decrease in the weight of the eggs in the cycles and the rate of production.

Table 17 gives the results of other correlations that have been calculated between the decrease in egg weight and the annual production.

The unweighted mean decrease in the weight of the eggs laid by the fowls whose record is shown in Table 17 was 1.11871 grams. This is a smaller decrease in the weight of the eggs in cycles than is shown in Table 15 with three year old hens, and inasmuch as the yearling hens in Table 17 show a greater decrease than the same birds when pullets, it appears probable that the extent of the decrease in the egg weight becomes greater as the fowls grow older.

TABLE 17.—Correlations Between Decrease in Weight and Annual Production.

Flocks	Number of Fowls	Age of Fowls	Decrease Computed for	Mean Decrease in Weight of Eggs Grams	Mean Annual Egg Production	Correlation Between Decrease and Annual Production
E	46	Pullets	Apr., May, June	1.00087	155.891	—.156±.097
F	45	Pullets	Apr., May, June	1.06622	142.933	—.059±.100
CD	38	Pullets	Apr., May, June	1.06500	134.184	—.365±.095
AB	42	Pullets	May, June	1.14286	135.283	—.485±.079
AB	43	Yearling	Apr., May, June	1.31860	150.442	+.035±.103

In Table 17 four of the five coefficients of correlation are negative. Two of the coefficients are significant and these results considered in connection with those given in Tables 15 and 16 indicate that the better the production the smaller is the decrease in the weight of the eggs in the cycles. This general principle is probably based on the physiological processes of the birds, and may represent a certain degree of fatigue or exhaustion of the reproductive organs when called upon to produce material for the daily egg. From these results it would appear that if the egg producing organs are easily fatigued so that there is a decided drop in the amount of egg substance produced from day to day, then the number of eggs laid will be at a low ebb.

TABLE 18.—Weight of Eggs Laid During May, 1923, by Bird 587. in Her Pullet Year.

Day of Month	Egg Weight	Day of Month	Egg Weight	Day of Month	Egg Weight
1	46.26	11	none	21	56.50
2	none	12	55.45	22	55.89
3	51.50	13	56.03	23	none
4	52.67	14	none	24	none
5	none	15	54.68	25	none
6	53.12	16	54.93	26	none
7	54.64	17	none	27	none
8	none	18	54.59	28	none
9	55.80	19	none	29	none
10	55.82	20	none	30	none
				31	none

With some birds the egg weight fluctuates in an unaccountable manner. Table 18 presents a case in which there are six two-egg cycles. In every instance except the last the second egg is heavier than the first.

Table 19 also presents a record in which the egg weights fluctuate widely.

TABLE 19.—Weight of Eggs Laid by Bird 567 During April, 1923.

Day of Month	Egg Weight	Day of Month	Weight Egg	Day of Month	Egg Weight
1	43.98	11	50.78	21	52.21
2	none	12	38.92	22	46.39
3	none	13	41.81	23	40.94
4	none	14	42.96	24	none
5	47.46	15	39.34	25	51.08
6	none	16	47.30	26	none
7	47.97	17	none	27	39.81
8	52.40	18	40.34	28	45.28
9	49.18	19	48.93	29	47.68
10	none	20	none	30	46.70

The weight of the eggs as shown in Table 19 is even more variable than those shown in Table 18. What causes these fluctuations? This question opens an attractive field for the study of the influence upon egg weight of various environmental factors, each of which may have an influence upon the weight as well as upon the number of eggs. **If the way can be pointed out for a more uniform production of egg substance from day to day this should pave the way for higher egg records.**

The results of this investigation indicate that the smaller the mean daily decrease in the weight of the eggs in the cycle the greater is the rate of egg production, also that the weight of the eggs in the cycle varies widely with many individuals and further study is needed to determine the reason for these fluctuations.

THE RESEMBLANCE OF SISTERS IN RESPECT TO THE MEAN WEIGHT OF THEIR EGGS

In breeding poultry for the production of eggs of more uniform size, it is important to know whether the mere selection of dams that lay eggs of the proper size will tend toward the production of progeny having the desired characteristics. In other words, do full sisters resemble each other more closely in respect to the size of their eggs than do the unrelated females of the same flock.

Source of Data Used

The mean annual weight of eggs laid during the pullet year by 177 White Leghorns is reported in Tables 1 to 5, inclusive, to which reference is here made for details regarding these fowls. The sires

of the birds in flock AB were nine not closely related males of unknown ancestry and about the same number of not closely related males were used in the production of flocks CD and EF.

Table 20 is inserted to show the method of analyzing the data and gives the record for flock CD for the pullet year.

TABLE 20.—Comparison of Birds in Flock CD Arranged in Families of Sisters.

Sisters	Mean Egg Weight	Average Egg Weight of Sisters	Departure From Average	Random Sample	Mean Egg Weight	Average Egg Weight	Departure From Average
403	53.0	51.90	1.10	439	50.7	50.60	.10
440	50.8		1.10	407	50.5		.10
411	52.4	50.55	1.85	435	52.9	51.95	.95
426	48.7		1.85	436	51.0		.95
434	50.3	50.20	.10	403	53.0	52.20	.80
428	52.5		2.30	422	52.3		.10
439	50.7		.50	409	52.7		.50
441	47.3		2.90	438	50.8		1.40
401	48.3	50.20	1.90	419	50.2	50.37	.17
402	52.5		2.30	408	46.7		3.67
404	51.2		1.00	424	51.8		1.43
427	48.8		1.40	432	52.8		2.43
424	51.8	50.25	1.55	413	49.5	51.20	1.70
418	48.7		1.55	442	52.9		1.70
435	52.9	51.80	1.10	431	51.5	50.10	1.40
405	50.7		1.10	418	48.7		1.40
406	49.6	50.67	1.07	405	50.7	53.07	2.37
420	52.9		2.23	406	49.6		3.47
413	49.5		1.17	410	58.9		5.83
415	45.8	48.13	2.23	416	50.5	49.70	.80
437	51.2		3.07	443	47.4		2.30
443	47.4		.73	404	51.2		1.50
407	50.5	54.70	4.20	415	45.8	48.30	2.50
410	58.9		4.20	440	50.8		2.50
409	52.7	50.55	2.15	426	48.7	49.95	1.25
421	48.1		2.45	401	48.3		1.65
432	52.7		2.15	423	49.8		.15
442	52.9		2.35	434	50.3		.35
408	46.7		3.85	425	50.2		.25
425	50.2		.35	411	52.4		2.45
431	51.5	50.77	.73	429	52.1	50.20	1.90
423	49.8		.97	437	51.2		1.00
436	51.0		.23	441	47.3		2.90
422	52.3	51.40	.90	402	52.5	52.70	.20
416	50.5		.90	420	52.9		.20
419	50.2	51.03	.83	421	48.1	49.80	1.70
438	50.8		.23	427	48.8		1.00
429	52.1		1.07	428	52.5		2.70

In Table 20 the birds in flock CD are arranged in families as shown in the first column. For example birds 403 and 440 were sisters, and so on. The second column shows the mean annual egg weights for the pullet year for each bird; column three gives the average of the mean egg weights for each family; column four shows the departure or variation in the mean egg weight for each bird from the average for the family; column five shows the birds arranged at random in groups of similar size to the families shown in column one, and columns six, seven, and eight correspond respectively to columns two, three, and four.

Table 21 shows the mean departure in egg weight of the birds from the average egg weight of the families to which they belong together with the standard deviation of these departures calculated for flocks AB, CD, and EF.

TABLE 21.—The Mean Departure and Standard Deviation in Egg Weight of Sisters, Compared with the Results from "Families" Consisting of Individuals Chosen at Random.

Items Considered	Flock AB	Flock CD	Flock EF
Number of birds	44	38	91
Number of families	14	13	29
Mean departure of sisters from average for the family	1.51±.12	1.63±.11	1.65±.08
Mean departure of "random sample" from average "for the family"	1.67±.13	1.52±.13	1.66±.09
Standard deviation of departures for sisters	1.20±.08	1.04±.08	1.18±.06
Standard deviation of departures for random sample	1.31±.09	1.21±.09	1.29±.06

There was no significant difference in the variability of the sisters in the same family as contrasted with each other, as compared with the variability of individuals chosen at random and thrown into similar "families". The data apparently justifies the conclusion that in order to obtain daughters having a reasonably uniform egg weight the mere selection of dams having the desired egg weight will not be sufficient for the purpose.

GENERAL SUMMARY

1. The birds whose individual records have been considered differed widely not only in respect to the number of eggs laid, but also in respect to the mean weight or average size of their eggs. The number of eggs laid in one year varied from 40 to 214, and the mean annual egg weight varied from $42.27 \pm .18$ grams to $64.65 \pm .17$ grams.

2. The rations which brought about a slow growth in the birds in flocks B, D, and F had the effect of reducing the number of eggs laid by these birds, particularly during the pullet year, but did not affect the size of the eggs.

3. The rations supplied to the birds in flocks B, D, and F while the birds were young seemed to have the effect of increasing variability, both in respect to the number of eggs laid and their weight.

4. The mean standard deviation in the weight of the White Leghorn eggs considered in this study was approximately 3 grams and varied from a minimum of $1.52 \pm .09$ grams to a maximum of $6.14 \pm .24$ grams.

5. The eggs attained almost their full weight during the second laying season. The increased weight for the second year as compared with the weight for the pullet year was approximately 9 per cent.

6. The average size of the eggs laid by a bird is a fixed definite and persistant characteristic.

7. The size of eggs depends, in part at least, upon the character of the ration fed. A ration consisting of whole grain only fed in winter reduced the weight of the eggs about 12 per cent.

8. As a rule, the greater the productive capacity of a bird, the smaller is the average decrease in the weight of the eggs which are laid on consecutive days.

9. During the period of maximum production, the decrease in the weight of the eggs laid on consecutive days is at a minimum.

10. With many birds, egg weight fluctuates from day to day in an unaccountable manner and further study of the reasons for these fluctuations is desirable.

BIBLIOGRAPHY

ATWOOD, HORACE
1914. SOME FACTORS AFFECTING THE WEIGHT, COMPOSITION, AND HATCHABILITY OF HEN EGGS. W. Va. Agr. Exp. Sta. Bul. 145.

1922. EFFECT OF CONFINEMENT AND GREEN FEED ON NUMBER AND HATCHABILITY OF EGGS. W. Va. Agr. Exp. Sta. Bul. 178.

1923. CERTAIN CORRELATIONS IN THE WEIGHT AND NUMBER OF EGGS AND THE WEIGHT OF FOWLS. W. Va. Agr. Exp. Sta. Bul. 182.

1925. STANDARD DEVIATION IN THE WEIGHT OF WHITE LEGHORN EGGS. W. Va. Agr. Exp. Sta. Bul. 195.

------------------------ and STEWART, J. H.
1900. POULTRY EXPERIMENTS. W. Va. Agr. Exp. Sta. Bul. 71.

------------------------ and WEAKLEY, CHAS. E.
1917. CERTAIN CHARACTERISTICS OF HENS EGGS. W. Va. Agr. Exp. Sta. Bul. 166.

BENJAMIN, E. W.
1920. A STUDY OF SELECTIONS FOR THE SIZE, SHAPE, AND COLOR OF HENS' EGGS. Cornell Agr. Exp. Sta. Mem. 31.

CARD, L. E., and KIRKPATRICK, WM. F.
1919. EGG LAYING CONTESTS. Conn. Agr. Exp. Sta. Bul. 100.

CURTIS, MAYNIE R.
1914. FACTORS INFLUENCING THE SIZE, SHAPE, AND PHYSICAL CONSTITUTION OF THE EGG OF THE DOMESTIC FOWL. Me. Agr. Exp. Sta. Bul. 228.

DRYDEN, JAMES
1899. POULTRY EXPERIMENTS. Utah Agr. Exp. Sta. Bul. 60.

1900. POULTRY EXPERIMENTS. Utah Agr. Exp. Sta. Bul. 67.

GILBERT, A. G.
1891. Report Experimental Farms (Canada).

HADLEY, PHILIP, and CALDWELL, DOROTHY W.
1920. STUDIES ON THE INHERITANCE OF EGG WEIGHT. R. I. Agr. Exp. Sta. Bul. 181.

JULL, M. A.
1924. EGG WEIGHT IN RELATION TO PRODUCTION. Poultry Science 3: 153-172.

LAURIE, D. F.
1912. Report of the Department of South Australia.

LIPPINCOTT, W. A.
1921. CORRELATION BETWEEN AGE AT FIRST LAYING AND SIZE OF FIRST EGG IN PULLETS. Jour. Amer. Assoc. Instrs. and Invests. Poul. Husb. 10: 73-74.

Bulletin 202 July, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Correlated Inheritance of Quantitative and Qualitative Characters in Oats

(Technical)

By

KARL S. QUISENBERRY

Publications of this station will be mailed free to any citizen of West Virginia upon written application. Address Director of West Virginia Agricultural Experiment Station, Morgantown, West Viriginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------President of the University
HENRY G. KNIGHT, Ph. D.--------------Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr.---------------------Agricultural Editor
JOHN C. JOHNSTON--Chief Clerk

AGRONOMY

R. J. Garber, Ph. D.
Agronomist
T. E. Odland, Ph. D.
Associate Agronomist
D. R. Dodd, M. S.
Assistant Agronomist
T. C. McIlvaine, Ph. D.*†
Assistant Agronomist
M. M. Hoover, M. S.
Junior Agronomist
H. K. Rowley, B. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
E. C. Stilwell, M. S.
Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist
Chas. E. Weakley, Jr., B. A.
Assistant Chemist
T. B. Leith, B. A.**
Assistant Chemist
T. J. Cochrane, M. S.
Junior Chemist
Paul Daughenbaugh
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman
H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman
G. Malcolm Trout, M. S.
Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
L. E. Dills, B. S.**
Assistant in Entomology

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
Paul A. Eke, Ph. D.
Assistant Farm Economist
F. D. Cornell, Jr., M. S.
Junior Farm Mechanician
W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D.
Home Economist
Nell Nesbitt, A. M.
Home Management Specialist

HORTICULTURE

Horticulturist
H. L. Crane, M. S. Agr.
Associate Horticulturist
H. E. Knowlton, Ph. D.
Associate Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
Ernest Angelo, M. S. Agr.
Junior Horticulturist
L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist
H. P. Sevy, B. S. Agr.
Assistant in Horticulture
A. L. Tener, B. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Assistant Plant Pathologist
L. H. Leonian, Ph. D.
Assistant Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D.
Associate Soil Technologist

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Sociologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

CONTENTS

*Correlated Inheritance of Quantative and Qualitative Characters In Oats**

The inheritance of quantitative characters, while of much interest from a practical as well as a scientific standpoint, has not been studied as extensively as that of qualitative characters. It is well known, however, that size characters are often very complex in their mode of inheritance, and frequently environment may cause reactions completely covering the effects of heredity. Because of this apparent complexity of inheritance, some geneticists formerly held that the laws formulated by Mendel did not hold for size characters. It is realized now that, as a rule, most, if not all, normal characters are the result of the interaction of many factors plus environment. East, Hayes, Emerson, and others, have furnished much evidence which proves that the inheritance of quantitative and qualitative characters can be explained on the same genetic basis.

LITERATURE REVIEW

General Methods Used in the Study of Inheritance of Quantitative Characters

The studies of the inheritance of size characters have been conducted in such a way as to determine whether certain mathematical requirements, as outlined by East (1916), were fulfilled. These requirements are, briefly, as follows:

1.—Crosses between homozygous individuals should give F_1 populations comparable to the parental races in uniformity.

2.—If the parents were homozygous, F_2 frequency distributions arising from extreme variants of the F_1 population should be identical, since the variation in F_1 should be due to environmental conditions.

3.—The variability of the F_2 population should be much greater than that of the F_1 population.

---

*The manuscript of this bulletin, with slight modifications, was presented to the Graduate Faculty, University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in June, 1925. The writer takes this opportunity to acknowledge the aid of various people in the preparation of this paper. Dr. H. K. Hayes, Professor of Plant Breeding, University of Minnesota, under whose direction the manuscript was prepared, gave valuable criticism and advice in the analysis of the data and the manner of presentation. Dr. R. J. Garber, Head of the Department of Agronomy, University of West Virginia, gave helpful advice in outlining the experiment, and in taking the data. Dr. Fred Griffee, Assistant Professor of Plant Breeding, University of Minnesota, made helpful suggestions as to the presentation of the data. Julia P. Quisenberry gave very efficient assistance in collecting and preparing the data.

The investigation reported in this bulletin was carried on at the West Virginia Agricultural Experiment Station as a part of a project on oat breeding. At the time this work was done and this manuscript prepared the author was Junior Agronomist in the Department of Agronomy, which position he resigned August 1, 1925.

4.—If enough F_2 individuals are grown, the grand-parental types should be recovered.

5.—In certain cases, individuals should be produced in F_2, showing a more extreme deviation than is found in either grand-parent.

6.—Individuals from different points on the frequency curve of the F_2 population should give F_3 populations differing markedly in their modes and means.

7.—Individuals either from the same or from different points on the frequency curve of an F_2 population should give F_3 populations of diverse variabilities extending from that of the original parents to that of the F_2 generation.

8.—In generations following the F_2, the variability of any family may be less, but never greater than the variability of the population from which it came.

Not all of these points are met in every cross studied, but they have been met many times in the studies made by various plant and animal geneticists and the agreement between the results and the mathematical requirements has, as a rule, been satisfactory.

The studies of linkage relations have furnished a valuable method of attack on the problem. By this method it is possible to study the factor or factors for size, if there be any present, in each known linkage group of a given plant. Such a method leads to a rather accurate determination as to the exact number of factors, or groups of factors, involved in certain size differences.

Sax (1923), working with beans, studied the relation of size of seed to pigmentation of the seed and found that factors, or groups of factors, for seed weight were linked with factors for pigmentation and pattern of the seed coat. In a cross Svanhals with Lion barley, Griffee (1925), studied the relation of resistance to *Helminthosporium sativum*, and certain morphological characters. He concluded that resistance to this disease was controlled by at least three factors, or groups of factors, apparently linked with the factors determining the character pairs six-rowed versus two-rowed, black versus white glumes, and rough versus smooth awn. The linkage was not complete as resistance or susceptibility could be combined with any desired morphological character. Similarly, Lindstrom (1924) found that in tomatoes small size of fruit was linked with colorless skin.

Quantitative Inheritance in Oats

Quantitative characters in oats have not been studied very extensively. Hayes and Garber (1921) have summarized the early work of Nilsson-Ehle. Two *Avena sativa* varieties differing in height

were crossed and transgressive segregation was obtained in F_2. Segregation was of a complex nature. Other crosses were made involving leaf breadth, kernel size, and number of florets to the spikelet. These crosses also gave transgressive segregation, and the results were explained on a multiple factor hypothesis, although the actual factors involuved could not be determined. Nilsson-Ehle obtained transgressive segregation for period of maturity in the F_2 of a cross between a medium early and a late maturing variety of oats. Progenies of 112 F_2 plants were continued in F_3, of which 98 segregated and 14 were homozygous, some being earlier than the early parent, and others later than the late parent.

Caporn (1918) crossed an early variety with a late maturing variety of oats. The F_1 and F_2 generations were not studied, but 106 lines were continued in F_3. Of the 106 lines continued two were considered to be as early as the early parent, although no lines were as late as the late parent. In twenty-two other lines, ripening extended over a period from the date of ripening of the early parent to that of the late parent. In some of these lines most of the plants ripened the first part of the period, in others the middle part, while in some lines the plants were mostly of late maturity. The remainder of the lines were more or less intermediate as to time of ripening. The results were explained on a three factor basis, the author suggesting that possibly the two early lines were homozygous for all three factors.

MATERIALS AND METHODS

Description of Parents

This paper presents the results of a cross between Victor (*Avena sativa*) and Sparrowbill (*Avena sativa orientalis*). The object being to study the mode of inheritance of length of the primary grain,* as well as any possible correlations of this character with other differential characters of the two parents.

The following description of the parents is taken from Etheridge (1916). Only those characters of interest in the present study are included in the description.

Victor.—"Panicles long, broad, coarse, wide-spreading, lax, the branches usually drooping from middle outward; spikelets two-grained, three-grained spikelets seldom occuring. . . . . grains black

*Note: In all species of oats other than *Avena nuda*, the flowering glumes adhere firmly to the grain proper, or caryopsis. The studies reported in this paper have to do with the length and color of flowering glumes of the primary grain, but, instead of referring each time to "flowering" glumes, the word "grain" will be used to designate caryopsis enclosed in its flowering glumes. This terminology is similar to that used by Surface (1916-7).

to brownish black, very large and coarse, outer grains usually 18-22 mm. long . . . . . . awns usually present, strong, coarse, twisted, often slightly geniculate."

Sparrowbill.—"Panicles thickly branched and fruited, compact, stiff, but sometimes slightly drooping at the apex, the branches appressed, ... spikelets two-grained, rarely three-grained, double grains very frequent, ... grains white, shading into pale yellow, outer grains remarkably short (12-15 mm.), plump, full,—awns wanting or rare."

The characters studied and the manner in which they entered the cross are given herewith in tabular form:

Victor	Sparrowbill
1. Grain long	1. Grain short
2. Grain black	2. Grain white
3. Grain awned	3. Grain awnless
4. Panicle open	4. Panicle side

Method of Growing Material

The crosses were made in 1922, at the West Virginia Agriculutral Experiment Station. To obtain seed for the crossing plots, an individual panicle was selected from a bundle of pure line material of each parent grown the previous year. All parental material grown in 1923 and 1924 traces back to these two original panicles.

The crossed grains were planted in the greenhouse in the fall of 1922, the F_1 generation maturing in time for planting in the spring of 1923. The F_2 generation was grown in 1923, with some additional F_1 plants and a small amount of parental material. In 1924, the F_3 generation was grown, as well as F_1, F_2, and parental material.

Sparrowbill and Victor Parents, and the F_1 of the Cross.

Sparrowbill Has Short, White Grains, and is Awnless. Victor Has Long, Black Grains and is Awned. The F_1 Generation Has Black Grains, is Nearly as Heavily Awned as Victor, and is Intermediate for Grain Length.

The method of planting was to space the grains every three inches in rows one foot apart. In 1923, twenty grains were planted per row, while, in 1924, the number was increased to twenty-five. At each end of the rows a stake was placed and outside of this stake three grains of the Victor parent were planted to give guard plants, in an attempt to reduce border effect. These border plants were pulled and discarded just before harvest. The F_3 lines were grown in plots consisting of two rows each; thus a total of fifty grains were planted. After each five plots of F_3 material, one plot of each parent was included, giving check plots at distantces of ten rows apart throughout the experiment.

Germination was poorer than expected in 1924, due to very cool, damp weather immediately following planting; therefore, the number of plants per row was reduced and the distance between plants was not always the same. No correction was attempted to reduce this error, as all F_3 lines, parents and F_2 material grown in 1924, were subjected to the same environmental conditions, and all reacted approximately the same.

A large number of plants of each parent were grown on good and poor soil in 1923 and 1924, in order to study the effect of soil condition on length or grain. This material was handled in the same manner as described above for the hybrids and parents.

In all calculations presented in this paper the method followed was to carry figures to one place further beyond the decimal point than is recorded in any of the tables.

Technique of Sampling

Preliminary to measuring the length of grain of the hybrids, some work was necessary to determine the correct size of sample to measure from each plant or on a single panicle, due to the time required. Not only was it necessary to study the size, but also the manner of taking the sample. No work was done to determine the variation between panicles of the same plant, but, in all cases, the leading panicle of each plant was used. In all cases, the measurements taken were on the primary grain.

Size of Sample

To determine the size of sample needed to give an accurate measure of the length of grain for a given plant, the following method was used. All the grains from the leading panicle of 117 Victor plants grown on good soil in 1923 were measured. The grains were removed from the panicle in an orderly manner from the base to the tip of the panicle. These grains were measured and the individual

lengths recorded in the same order in which they were removed from the panicle.

Samples of five, ten, and fifteen measurements were selected from the data on each panicle, by taking measurements from all parts of the panicle. For example, if a panicle had thirty grains, the sample of five grains was selected by taking the measurement of the fourth, tenth, sixteenth, twenty-second, and twenty-eighth grains. In taking the different size samples, care was exercised so as not to use a given measurement more than once, unless absolutely necessary. The 117 means for a given size sample were placed in frequency distributions, as shown in Table 25 of the appendix. A summary of this data is given in Table 1.

TABLE 1.—Statistical Constants for Different Size of Samples of Grains Measured on the Leading Panicle of Plants of Victor Oats Grown on Good Soil 1923.

Number of Grains in Sample	Mean Length of Grain in Millimeters	Standard Deviation	Probable Error Single Determination
5	17.82 ± 0.05	0.86 ± 0.04	0.58
10	17.80 ± 0.06	0.88 ± 0.04	0.59
15	17.79 ± 0.05	0.84 ± 0.04	0.56
All Grains	17.77 ± 0.05	0.82 ± 0.04	0.55

In no case is there a difference of practical importance in the means of the sample of five, ten, fifteen, or all of the grains on the panicle. Likewise, the standard deviations are of about the same value. These figures seem to show that, for this experiment, samples of five, ten, or fifteen grains have approximately as accurate a measure of length of grain as that obtained by measuring all the grains in the panicle. It was decided to measure a sample of ten grains from the main panicle of each plant.

Variation of Length of Grain at Different Places on the Panicle.— For this study plants of the Victor parent grown on good soil were used. As stated previously, the grains from the panicles were removed in order, the measurements also being recorded in order. To determine if there was any increase in length of grain in one part of the panicle over another, the measurements were grouped by fives from the base to the tip of the panicle, and the means determined for each of these groups. Panicles with approximately the same number of grains were compared and the means for the average measurements of the first, second, third, etc., groups from the bottom were

determined. These data are presented in Table 26 of the appendix. This table also gives the number of groups, the number of plants going to make up the mean, the approximate number of grains per panicle, and the mean length for the group with its probable error. The number of grains per panicle varied from fifteen to fifty; no panicles being included unless they contained at least fifteen grains. In all cases only full groups of five grains were considered. For example, if a panicle had twenty-eight grains, five groups were taken, the three grains at the tip being disregarded.

The number of plants with different sized panicles ranged from nine with three groups of five grains each, to twenty-one with six and seven groups each. The probable errors of the means were determined by Bessel's formula,* and all are of nearly the same value.

In order to determine if there was a significant increase in length of grain as the tip of the panicle was approached considering all of the plants, comparisons were made between the first and mid group, mid and last group, and the first and last group. In this comparison Student's method was used to calculate the probabilities. These calculations will be found in Table 2. The first column gives the number of groups per panicle; the other columns indicate the difference in length between the first and mid group, mid and last, or

TABLE 2.—Differences in Mean Length of Grains Between the First, Mid, and Last Groups on the Panicle. Probabilities Calculated According to Student's Method. Victor Parent Grown on Good Ground 1923.

Number of Groups on the Panicle	Difference in Millimeters Between		
	First and Mid Group	Mid and Last Group	First and Last Group
3	+0.10	+1.00	+1.10
4	+0.35	+0.65	+1.00
5	+0.20	+0.80	+1.00
6	+0.05	+1.05	+1.10
7	+0.60	+0.60	+1.20
8	+0.35	+0.95	+1.30
9	+0.30	+0.60	+0.90
10	+0.55	+0.15	+0.70
Mean Difference	+0.31	+0.73	+1.04
σ of Dierence	0.18	0.28	0.17
Value of Z	1.72	2.61	6.12
Odds	765:1	Significant	Significant

$$* \pm .6745 \sqrt{\frac{\Sigma d^2}{n\ (n-1)}}$$

ff

first and last groups. In the panicles having an even number of groups, the figure for the mid group was the mean of the two mid groups.

In all cases the differences are plus; in other words, the grains are longer nearer the top of the panicle. Comparing the mean differences, it is seen that there is greater increase between the mid and last groups than between the first and mid groups. Using Student's method, the value of Z* was calculated. Referring to the tables prepared by Love (1924) for the Z values, the odds are 765:1 against a difference as great as the one shown between the first and mid groups being due to chance. Between the mid and last groups, the chances are over 9,999:1 against as great a difference as the one shown being due to chance, while for the first and last group, the value of Z is more than two times that of the second case; therefore, the difference is certainly significant.

Under the conditions of the experiment it is shown that there is a gradual increase in length of grain from the base to the tip of the panicle and that this increase is greater from the middle part to the tip than from the base to the middle.

From these results it was decided to select the samples of 10 grains at random from all parts of the panicle.

Variability of Grain Length of Parents

Influence of Soil Condition on Length of Grain.—In order to determine what effect, if any, the productivity of the soil has upon the length of grain, each parent was grown on good and poor soil in 1923 and 1924. The plot designated as "good" was a productive piece of ground, on which previous crops had been making very good growth. During the winter, a heavy application of manure was applied and, just before planting each spring, acid phosphate at the rate of 200 pounds per acre was added. The "poor" plot in 1923 was on some very thin, rocky soil on which previous crops had been very poor. No manure or fertilizer was added. In 1924, the poor plot was in a location which seemed to be in a less productive condition than the plot used in 1923.

In 1923, 240 grains were planted for each parent, while the number of plants harvested varied from 117 to 143. In 1924, 300 grains were planted and the number of plants harvested ranged from 206 to 232.

As a check on the vigor of the plants the individual plant heights and yields were taken. These data are given in Table 3.

Considering Table 3, it is apparent that the grain length of the Victor parent was little influenced by soil condition in 1923, the dif-

*$Z = \frac{m}{\sigma}$

ference being only about twice the probable error. In 1924, the grain length of the Victor parent was 0.44±0.04 millimeters less on poor soil than on good soil. This difference is 11 times the probable error and the odds that a difference as great as this is not due to random sampling are very great.

TABLE 3.—Comparison of Victor and Sparrowbill Parents Grown on Good and Poor Soil, 1923-1924.

Parent	Soil	Year	Length of Grain in mm.	Yield per Plant in gms.	Height of Plant in cm.
Victor	Good Poor	1923	17.80±0.06 17.96±0.05	5.89±0.21 4.07±0.10	109.12±0.50 93.44±0.40
Victor	Good Poor	1924	17.14±0.03 16.70±0.03	3.97±0.09 3.55±0.06	109.03±0.32 98.78±0.30
Sparrow-bill	Good Poor	1923	13.23±0.03 13.37±0.02	5.93±0.21 2.83±0.10	109.76±0.60 86.76±0.51
Sparrow-bill	Good Poor	1924	12.15±0.02 12.21±0.02	4.47±0.09 3.75±0.07	112.68±0.33 100.00±0.41

For the Sparrowbill parent there was little difference on the two soil types in the results obtained for length of grain. The poor plot gave grains 0.14±0.04 millimeters longer than the good plot. This difference is 3.5 times the probable error, the odds being about 54:1 that a difference as great as this is not due to random sampling, although the actual increase in length is very small. In 1924, the difference in the results obtained on the two plots is very small and not significant.

The data on height and yield of individuals are included for the purpose of giving an indication of the productivity of the two plots. The results obtained prove conclusively that there was considerable difference between the plots. From this it was concluded that length of grain, while showing some variability due to soil productivity, was not as greatly influenced as such characters as yield and height of plant.

Variation of Grain Length of Parental Varieties in Check Plots.—It has been learned that soil conditions have some influence on length of grain. Tables 27 and 28, presented in the appendix, give the data on the various plots of each parent grown as check plots in 1924.

A study of the means and their probable errors given in these two tables indicates that there are deviations between the various

plots of the same parents, which, in the light of their probable errors, are mathematically significant.

To study the extent of soil heterogeneity of the plot on which the hybrids and parents were grown, several correlations were made. The parents were grown in adjacent plots and were distributed uniformly throughout the experimental field at distances apart of ten rows. In each parent the average length of grain of the plants of the first plot and those of the second, the second with the third plot, etc., were correlated. For the Victor parent $r = +0.376 \pm 0.112$ and for Sparrowbill $r = +0.374 \pm 0.114$. The correlations are of nearly the same magnitude and are both slightly more than three times their probable errors. By reducing the means of the various plots of the parents to a percentage basis, it was possible to place the data of both parents in the same correlation table, thus doubling the number of individuals and reducing the probable error. By this method $r = +0.377 \pm 0.079$. By using the standard error of estimate* a correlation of this magnitude indicates that, for plots ten rows apart, soil heterogeneity affects total variability of length of grain 7.4 per cent. Since the parents were grown in paired plots, it was possible to correlate the grain length of the plants of one parent plot with that of the other. For such a comparison $r = -0.134 \pm 0.110$, indicating no correlation. The fact that there is no correlation between grain length of one parent and the other in adjacent plots shows that the two varieties do not react the same to soil variations.

In order to determine if the actual stand per plot must be considered, the number of plants per plot which survived was correlated with mean length of grain per plot. In Victor $r = +0.105 \pm 0.111$ showing no significant correlation; while, for Sparrowbill, $r = -0.573 \pm 0.076$, showing that a reduced number of plants tend to allow an increase in length of grain. In both cases the number of variates entering these correlations are quite small, being only thirty-six individuals. It would seem that the number of plants per plot influences the variability of length of grain in Sparrowbill about 18 per cent. This shows the desirability of having approximately the same number of plants in each plot.

INHERITANCE OF CHARACTER DIFFERENCES

Length of Grain

A summary of the data for segregation of length of grain in the F_1 and F_2 generations of the cross Sparrowbill with Victor and reciprocal is given in Table 4. Included in this table are the data for

* $100 \times 1 - \sqrt{1 - r^2}$

TABLE 4.—Length of Grain of Parents, F_1 and F_2 Hybrids. Sparrowbill Crossed With Victor and Reciprocal.

Name	Year	Plants with Length of Grain in Millimeters										Total No. Plants	Mean Length of Grain in Millimeters	Standard Deviation	Coefficient of Variability
		10	11	12	13	14	15	16	17	18	19				
Victor Parent	1923							1	28	20	4	53	17.51±0.06	0.66±0.04	3.77±0.25
Victor Parent	1924						56	747	455	32	1	1291	16.36±0.01	0.61±0.01	3.73±0.05
Sparrowbill Parent	1923			13	53	4						70	12.87±0.04	0.48±0.03	3.73±0.21
Sparrowbill Parent	1924	29	620	629	12	4						1290	11.48±0.01	0.56±0.01	4.88±0.06
Sparrowbill x Victor F_1	1923							2				2			
Victor x Sparrowbill F_1	1923							2				2			
Victor x Sparrowbill F_1	1924						2	1				3			
Sparrowbill x Victor F_2	1923			1	4	21	41	57	25	3	1	153	15.57±0.06	1.13±0.04	7.26±0.28
Victor x Sparrowbill F_2	1923			4	18	67	123	138	70	10	2	432	15.46±0.04	1.20±0.03	7.76±0.18
Sparrowbill x Victor F_2	1924			5	44	61	53	22	4			189	14.29±0.05	1.09±0.04	7.63±0.26
Victor x Sparrowbill F_2	1924			14	47	85	44	28	5		1	224	14.20±0.05	1.20±0.04	8.45±0.27

the parental material grown in 1923 and 1924. All the plants of one parent grown the same year are placed in one frequency distribution.

The number of parent plants grown in 1923 was rather small, due to lack of seed. It will be noticed from this table that the average length of grain of both parents was more than one millimeter shorter in 1924 than in 1923. There was a greater difference between the two parents in 1924 than in 1923 as the grain length of Sparrowbill was reduced more by environmental conditions than was Victor.

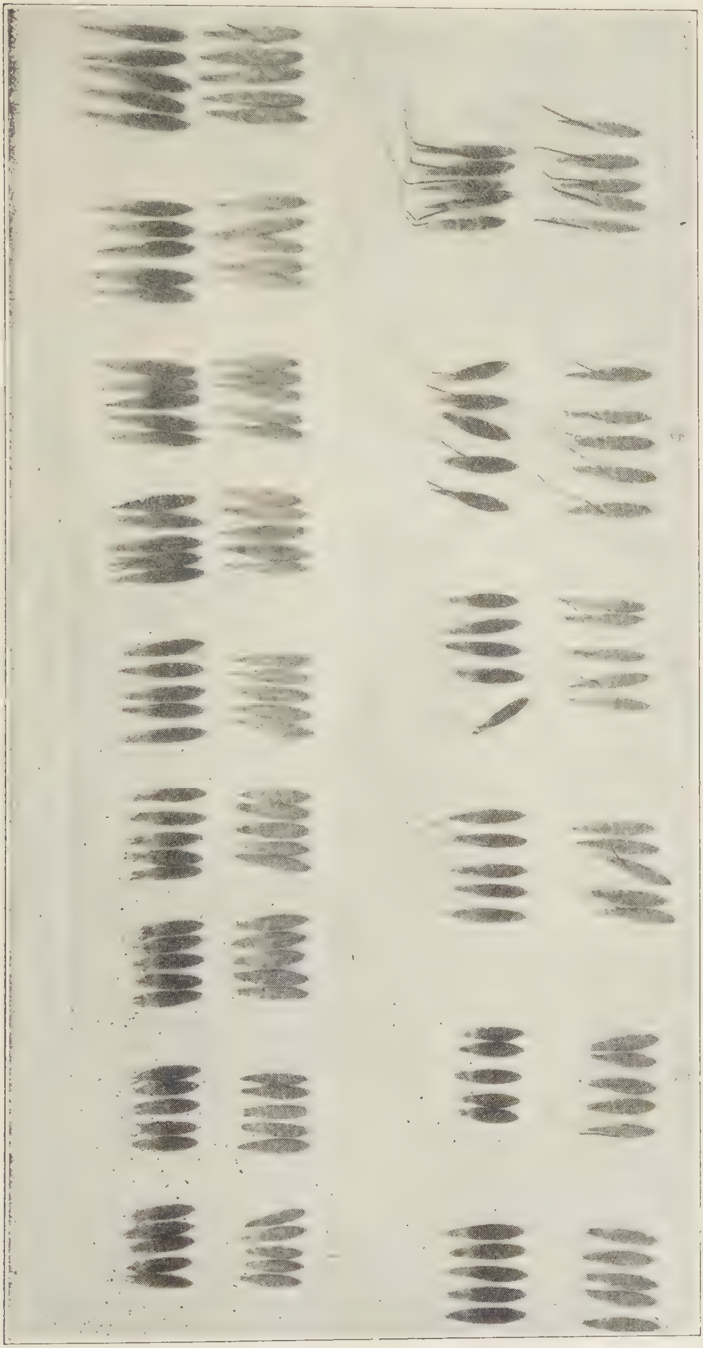
The few F_1 plants grown were intermediate in grain length (see illustration on page ~~6~~), 8 although they are nearer the Victor than the Sparrowbill. The coefficients of variability of the F_2 generation were about twice as large as for the parents. It will be noted that in no case was there transgressive segregation in F_2. In 1923, plants with grains as short as Sparrowbill and others with grain as long as Victor were obtained (see illustration on page ~~15~~). 17 In 1924, the upper limit was reached, while no plants were found with grains shorter than twelve millimeters, which is two millimeters longer than the shortest Sparrowbill grains obtained that year. As was the case with the parents, the mean length of grain of the F_2 plants was shorter in 1924 than in 1923.

To obtain a more accurate indication as to the behavior of the hybrids for length of grain, seventy-five families of Sparrowbill crossed with Victor, and seventy-five families of the reciprocal, were continued in F_3. The number of plants in each family varied from twenty to forty-five, with the exception of four families which contained less than twenty plants. It is realized that a larger number of plants per family would have been more desirable, but this would have necessitated growing fewer families, since the time required to measure the grains from a plant limited the amount of material which could be studied.

Detailed data consisting of the mean and the coefficient of variability of each F_3 family grown in 1924 as well as the mean length of grain of each F_2 parent plant are given in Tables 29 and 30 of the appendix.

To determine the extent to which grain length in F_2 was a result of inheritance, a correlation coefficient was calculated for average grain length of the F_2 plants in relation to their F_3 breeding behaviour (see Table 5). A correlation coefficient of $+0.705\pm\cancel{0.28}$ was obtained, which indicates that the character studied is an unusually stable one for a size character.

0.028



Upper: Segregation Obtained for Length of Grain. Top Row, Black Grains; Bottom Row, White Grains. Numbers Denote Grain Length in Millimeters. Awns Have All Been Removed.

Lower: Segregation Obtained for Awn Development. Top Row, Black Grains; Bottom Row, White Grains. Numbers Represent Awn Classes.

TABLE 5.—Relation of Length of Grain on F_2 Plants and Mean Length of Grain of F_3 Family.

Length of F_2 Grain	Classes for Mean Length of Grain in F_3 Family in Millimeters											Total
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	
13.0	1	1										2
13.5		1	1	2	1	1						6
14.0		1	4	2								7
14.5			2		4	1						7
15.0			6	6	10	3	2	2				29
15.5			2	4	8	8						22
16.0				1	9	5	8	3	1	1		28
16.5				2	2	4	11	1	1			21
17.0						5	5	2	3	1		16
17.5					1		4	1	2			8
18.0								1			1	2
18.5							1		1			2
Total	1	3	15	17	35	27	31	10	8	2	1	150

$r = +0.705 \pm 0.028$

The coefficient of variability may be used as an indication as to whether an F_3 family is segregating for grain length, the variability of the parental material being used as a criterion of the homozygous condition. The mean grain length of each family is given in Table 6 with respect to the coefficient of variability for the family. The coefficients of variability were grouped into classes of 1.0 per cent, while the classes for the length of grain were 0.50 millimeters. The parents and F_2 data are presented for comparison. In the Victor parent in 1924 the coefficient of variability of the means obtained in different plots varied from 1.5 per cent to 4.5 per cent, while, in the Sparrowbill for the same year, the range was from 3.5 per cent to 6.5 per cent. On this basis any F_3 family with a coefficient of variability of 4.5 per cent or less was considered as probably homozygous for length of grain. For the shorter grained families those with a coefficient of 6.5 per cent or less are possibly homozygous. It is apparent that about two families may be considered as homozygous for short grain and about four for long grain. Between these two extremes there are families which are apparently homozygous for grain of intermediate lengths.

It is evident that the type of segregation displayed here is typical for size inheritance, and may be explained on a multiple factor basis. The following explanation is suggested on a three factor basis. The difference in grain length between the parents in 1924 was 4.9 millimeters. Assuming that each of the three factors has an equal influence on grain length, or 1.6 millimeters increase when homozygous there should be in F_3, on a basis of sixty-four families, one family breeding true for a length of 16.3 millimeters, three families breed-

TABLE 6.—Average Length of Grain in Relation to the Coefficient of Variability of F_2 and F_3 Families of a Cross Victor with Sparrowbill, and Reciprocal. Grain Lengths of Parents are Included for Comparison.

Name	Year Grown	Gen-era-tion	Coefficient of Variability in Classes	Classes for Average Grain Length of Hybrid and Parent Families in Millimeters													Total Families
				11.25	11.75	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	
Victor	1923		3.5													1	1
Sparrowbill	1923		3.5				1										1
Spb. x Vic.	1923	2	7.5										1				1
Vic. x Spb.	1923	2	7.5									1					1
Victor	1924		1.5											1			1
			2.5											6	1		7
			3.5										1	14	6		21
			4.5										1	3	3		7
Total Families																	36
Sparrowbill	1924		3.5	1	5												6
			4.5	13	11												24
			5.5	5													5
			6.5	1													1
Total Families																	36
Spb. x Vic.	1924	2	7.5								1						1
Vic. x Spb.	1924	2	8.5								1						1
Spb. x Vic.	1924	3	3.5								2	0	1				3
			4.5				1	3	1	1	3	1	0	1			11
			5.5				2	4	2	3	3						14
			6.5		1	3	1	0	8	5	5	2	1				26
			7.5			1	4	3	1	5	4						18
			8.5		1					1							2
			9.5				1										1
Total Families																	75
Vic. x Spb.	1924	3	4.5				1	3	2			1		2			9
			5.5				6	2	8	5	2	1	2				26
			6.5	1		2		5	5	5	3						21
			7.5		1	1	1	5	8			2					18
			8.5							1							1
Total Families																	75

ing true for a length of 14.7 millimeters, three families breeding true for a length of 13.1 millimeters, and one family breeding true for grain 11.5 millimeters long. In Table 7 these calculated figures are compared with the observed F_3 data.

TABLE 7.—Comparison of Observed and Calculated Number of F_3 Families Homozygous for Various Grain Lengths.

Kind of Ratio	Families Homozygous for Grain Length in Millimeters of				Total
	16.3	14.7	13.1	11.5	
Calculated	2.4	7.2	7.2	2.4	19
Observed	2.0	5.0	8.0	4.0	19

To definitely establish limits between families homozygous and heterozygous, for different lengths of grain, is only a rough approximation, the real test being a more extensive breeding study or the actual locating of the factors for length of grain in definite linkage groups. It is easily demonstrated that a line segregating for one factor pair might give differences in length so small that they could not be distinguished from environmental fluctuations.

In the preceeding paragraph it is shown that apparently each factor pair for grain length when homozygous gives an increase in length of 1.6 millimeters. If each of the three factors had half the influence in the heterozygous condition as when homozygous the F_1 plants would have grains which averaged about 13.9 millimeters in length. The F_1 plants grown in 1924, however, had grains which averaged 15.3 millimeters in length indicating that each factor in the heterozygous condition increases the length of grain 1.2 millimeters.

Color of Grain

In the cross under consideration, the Victor parent has black grain and Sparrowbill parent white. All the F_1 plants produced black grain, possibly not as intense in color as Victor. The segregation for color in F_2 for all families grown is presented in Table 8.

In all cases the observed numbers are very close to the calculated for a 3:1 ratio. For the totals the deviation divided by the probable error is 1.5, indicating that black and white color are probably controlled by a single factor difference.

To test the accuracy of the F_2 classification for grain color the breeding behavior of the F_3 families was studied in relation to the classification for grain color of the parent F_2 plant. The detailed

breeding behavior of the various families are presented in Tables 31 and 32 of the appendix, and are summarized in Table 9. Two plants were classed as black in F_2 when, actually, they were white. This is easily accounted for, since color does not develop exceptionally well under the moist growing conditions of West Virginia. The results obtained, however, prove that, in general, the F_2 classification for grain color was approximately correct.

TABLE 8.—Inheritance of Grain Color in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

Cross	Year	Total Number of Plants in F_2 with Grain		Total
		Black	White	
Sparrowbill x Victor	1923	116	37	153
Victor x Sparrowbill	1923	332	100	432
Sparrowbill x Victor	1924	146	43	189
Victor x Sparrowbill	1924	169	55	224
Total observed		763	235	998
Calculated 3:1		748.5	249.5	998

Deviation=14.50. P. E.=9.23. Dev./P. E.=1.5.

TABLE 9.—Summary of Breeding Behavior of F_3 Families for Color of Grain.

Name	F_2 Color Description	F_3 Breeding Behavior			Total
		Black	Segregating	White	
Sparrowbill x Victor and Reciprocal	Black	35	73	2	110
	White			40	40
Total		35	73	42	150

X^2 = Less than 1. P = Very good.

The data for the segregation for black and white grain color agree in general with the results obtained by Wilson (1907), Gaines (1917), Zinn and Surface (1917), Love and Craig (1918), Wakabayashi (1921) and Nilsson-Ehle (1909).

Panicle Type

As pointed out in the description of the parents, Sparrowbill has a side or "horse mane" type of panicle, while Victor has an open or branched panicle. The F_1 of the cross between these two varieties was open-panicled. In the F_2 generation the ratio of open-panicled plants to side-panicled was close to a 15:1 calculated on the basis of a two factor difference, the factors for open panicle being duplicate (see Table 10).

TABLE 10.—Segregation for Panicle Type in F_2 Plants of the Cross Sparrowbill with Victor and Reciprocal.

Cross	Year	Total Number of Plants in F_2 with Panicles		Total
		Open	Side	
Sparrowbill x Victor	1923	143	10	153
Victor x Sparrowbill	1923	403	29	432
Sparrowbill x Victor	1924	174	15	189
Victor x Sparrowbill	1924	210	14	224
Total observed		930	68	998
Calculated 15:1		936	62	998

Deviation = 6. P. E. = 5.16. Dev./P. E. = 1.1.

In selecting the F_2 plants to continue in F_3 more plants classed as side in F_2 were continued than probably would have been had the selection been entirely at random. For complete data on the F_3 families for panicle type see Tables 31 and 32 in the appendix. These data are summarized in Table 11.

TABLE 11.—Breeding Behavior of the F_3 Families for Panicle Type.

F_2 Panicle Description	F_3 Breeding Behavior			Total
	Open	Segregating	Side	
Open	65	68		133
Side		7	10	17
Total	65	75	10	150

In all cases F_2 plants classed as open bred true for open panicle or segregated in F_3. In the case of plants classed as side in F_2, seven segregated; showing that, in reality, they should have been classed as open. If the classification of the F_2 material grown in 1923 is corrected on a basis of the breeding behavior of the F_3 the observed ratio would be 562:23. The calculated is 548:37, giving a deviation of 14, which is 3.5 times the probable error, giving odds of about 54:1 against a deviation as great as the one observed being due to chance alone.

The F_3 lines which were grown may be used to determine whether the breeding behavior for panicle type could be explained on the two factor hypothesis. Had the same per cent of F_2 plants classed as side panicle been continued in F_3, as were F_2 plants classed as open, ten would have been grown instead of seventeen. According to the breeding behavior of the 17 F_2 side plants continued, 41 per cent, or seven, segregated. On this same basis on the average four out of ten plants would be expected to segregate in F_3. Combining these data with the breeding results of the open panicle F_2 plants, it is found that sixty-five bred true for open panicle, seventy-two segregated, and six bred true for side panicle. The calculated breeding behavior on the two factor basis is 63:71:9. Comparing these two results by the X^2 method gives a P. of .5880. The data obtained in this study indicate that the parents differed in two main factors for panicle type, one or both factors in the dominant condition giving open panicles. These results agree with those obtained by Nilsson-Ehle (1909), while Garber (1922) found that in Minota or Victory crossed with White Russian the results were best explained on a single factor difference. Wakabayashi (1921) states that in a cross Red Rust Proof with Black Tartarian, the inheritance of shape of panicle, if Mendelian, is probably best explained on a basis of multiple factors. Variable results, not explainable on a single factor basis, are reported by Gaines (1917) in crosses of side-panicled with open-panicled types.

Degree of Awn Development

The variety Victor carries a rather heavy, black twisted, geniculate awn on the primary grain, while the Sparrowbill variety is awnless in most cases (see illustration on page ~~6~~8). Occasionally, however, one or two primary grains in a panicle of Sparrowbill will be awned, the strength of the awn varying from very weak to a rather short, black twisted, but rarely geniculate awn. In no case was the awn of Sparrowbill nearly as long or as heavy as on Victor. In

taking the awn notes an arbitrary scale of numbers from "0" to "5" was used. The total absence of awns was denoted by "0", while "1" indicated the presence of one or two awns in the panicle. More than two grains with awns were indicated by "2", while "3" represented a more or less intermediate condition between the two parents as to number and strength of awn. A plant classed as "4" had practically all of the primary grains awned, but the awns were not all geniculate, while "5" indicated the presence of a black, twisted, and geniculate awn on every primary grain in the panicle. (See illustration on page 15).17

Unfortunately but few data were taken to determine the variability of the two parents for awns (see Table 12). A study of the data taken, however, indicates that both parents vary with respect to awns, the Sparrowbill giving all "0" and "1" types, while the Victor gives mostly "5," with a few "4" types.

The awns of the F_1 plants of this cross were of an intermediate type, not quite as heavy as the Victor parent, and were classed as "3" or "4". A summary of awn development of the F_2 material grown in 1923 and 1914 is given in Table 12.

TABLE 12.—Behavior of Awn Development in F_2 and Parent Plants Grown in 1923 and 1924.

Name	Year	Number of Plants in F_2 With Awns Classed as						Total
		0	1	2	3	4	5	
Victor	1923					5	35	40
Sparrowbill	1923	35	19					64
Sparrowbill x Victor	1923		15	25	55	27	31	153
Victor x Sparrowbill	1923	9	36	68	129	105	85	432
Sparrowbill x Victor	1924	2	15	11	24	75	62	189
Victor x Sparrowbill	1924	3	15	22	41	75	68	224
Total for Hybrids		14	81	126	249	282	246	998

The detailed breeding behavior for awns of the hundred and fifty families grown in F_3 is given in Tables 31 and 32 of the appendix. The results are summarized in Table 13.

In the classification of the F_3 families for awns, the awnless class includes those lines which were as awnless as Sparrowbill. In the "awnless dominant" class most of the plants were awnless, although a few plants were present with stronger awns. The "like F_2" class showed segregation similar to that of F_2 The "awns dominant" class consisted of those lines in which awned plants predominated; while "awned" group consisted of such lines as bred as truly awned as the Victor parent.

TABLE 13.—Summary of Breeding Behavior of F_3 Families for Awns.

F_2 Awn Class	Classification of F_3 Families for Awns					Total
	Awnless	Awnless Dominant	Like F_2	Awns Dominant	Awned	
0	1					1
1	1	3	13			17
2		1	22	2		25
3		2	34	16	1	53
4			8	23	4	35
5			3	11	5	19
Total	2	6	80	52	10	150

The data obtained indicate a close relation between the F_2 classification and the breeding behavior in F_3. The only plant classed as "0" in F_2 that was continued bred awnless. The "1" class gave a predominating number of families segregating like F_2. The "2" and "3" classes gave a more or less segregating type of F_3 reaction, while "4" and "5" classes tended to give mostly awns dominant and awned F_3 lines.

The expression of awns is quite variable, and apparently considered influenced by environment. Because of the fact that no extensive notes are available regarding the variation of awns on the parents from one part of the field to another, a careful analysis of the hybrids is impossible.

Previous workers, studying the inheritance of awns have reported varying results. Norton (1907), by crossing awned and awnless forms obtained a ratio in F_2 of 1 awned: 2 hybrid type: 1 awnless. In crosses between *Avena fatua* and Kherson, Surface (1916) found that the factors for awns behaved as a simple Mendelian factor pair, giving 3 awned to 1 not fully awned. In F_3, however, the awnless plants failed to breed true in all cases; in fact, only five lines in twenty gave all awnless forms. Surface concludes that the character is very variable. Love and Frazer (1917) in a cross Burt (weak awned) with 60 Day (awnless) obtained a ratio in F_2 of 1 awnless: 2 intermediate: 1 awned. The awned plants bred true, the intermediate plants again segregated, while some of the awnless plants bred true and others were heterozygous. They considered that awning was influenced by environment. Love and Craig (1918), in a cross 60 Day with *Avena fatua* found fully awned recessive to weak awn. Fraser (1919) in crosses between strong and weak awned parents found the fully awned type recessive. Awnless F_2 plants failed to breed true in all cases. Some of these variable results were

explained by an inhibiting factor linked with the factor for yellow color in 60 Day. Fraser also states that awns are influenced by environment.

The present study probably deals with material behaving in much the same way as the weak awn condition reported by Love and Fraser, Love and Craig, and Fraser. In the work here, very few families were obtained which bred true for awnlessness, and relatively few bred true for strong awns, although there were more homozygous awned than awnless lines. It is hardly possible to explain the segregation on a single factor difference.

CORRELATED INHERITANCE OF CHARACTERS

A further object of this study was to determine any possible genetic linkages, if such occurred.

Relation of Length of Grain and Color of Grain

Data regarding the relation between grain length and color of grain in the F_2 generation of the cross Sparrowbill with Victor and reciprocal grown in 1923 and 1924 are presented in Table 14. In Table 15 are given data on the length of grain of the various F_3 families, homozygous for white or black color or segregating.

TABLE 14.—Relation of Length and Color of Grain in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

Year	Color of Grain	Frequency Distribution for Grain Length in Millimeters								Total	Mean	Difference	Dif./P.E.
		12	13	14	15	16	17	18	19				
1923	Black	4	16	69	122	145	77	12	3	448	15.52±0.04	0.12±0.07	1.7
1923	White	1	6	19	42	50	18	1		137	15.40±0.06		
1924	Black	15	72	112	70	39	6			314	14.20±0.04	0.12±0.09	1.3
1924	White	4	19	34	27	11	3			98	14.32±0.09		

From the date of the F_2 generation it is seen that there was no difference in grain length, between the black and the white plants. This same condition was found in the F_3 generation since there was no significant difference in length of grain between families homozygous for white grain and families homozygous for black grain. There was no significant difference in length of grain between the families segregating for color and either the black or white families. It seems safe to assume that there is no linkage between factors for length of grain and color or grain.

TABLE 15.—Breeding Behavior of F_3 Lines of the Cross Sparrow-with Victor and Reciprocal for Grain Length and Grain Color, Grown in 1924.

Color Behavior of Line	Mean Length of Grain in F_3 Families in Millimeters											Total	Mean	Difference	Dif./P.E.
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5				
Black		1	3	4	5	3	10	5	3	1		35	14.10±0.11	Black & White +0.23±0.14	1.6
Seg.	1	1	9	8	20	13	13	4	4			73	13.73±0.07	Black & Seg. +0.37±0.13	2.8
White		1	3	5	10	11	8	1	1	1	1	42	13.87±0.09	Seg & White +0.14±0.11	1.3

Relation of Length of Grain and Panicle Type

The data on the relation of length of grain and panicle type in the F_2 families grown in 1923 and 1924 are presented in Table 16, while the F_3 breeding behavior for these two characters is given in Table 17. In both years the open panicled plants had the longer grain.

TABLE 16.—Relation of Panicle Type and Length of Grain in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

Year	Panicle Type	Frequency Distribution for Grain Length in Millimeters								Total	Mean	Difference	Dif./P.E.	Odds
		12	13	14	15	16	17	18	19					
1923	Open	3	18	80	151	187	91	13	3	546	15.54±0.03	+0.69±0.14	4.9	1051:1
1923	Side	2	4	8	13	8	4			39	14.85±0.14			
1924	Open	15	81	134	96	48	9		1	384	14.29±0.04	+0.74±0.14	5.8	1350:1
1924	Side	4	10	12	1	2				29	13.55±0.13			

From these data it is seen that homozygous open panicle families had grain 1.27±0.14 millimeters longer than homozygous side panicle families. This difference is significant in the light of its probable error. The segregating rows are intermediate in length of grain between the side and open families, although they are nearer the homozygous opens in grain length than they are to the sides. The data for the F_2 and F_3 generations agree in general, bringing out the fact that side panicle plants have grains shorter than open-panicled plants.

TABLE 17.—Breeding Behavior of F_3 Lines of the Cross Sparrowbill with Victor and Reciprocal Grown in 1924.

Panicle Behavior of Line	Mean Length of Grain in F_3 Families in Millimeters											Total	Mean	Difference	Dif./P.E.
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5				
Open			3	3	16	14	19	4	5	1		65	14.12±0.06	Open & Side +1.27±0.14	9.3
Seg.		3	9	11	16	13	12	6	3	1	1	75	13.84±0.07	Open & Seg. +0.28±0.09	3.1
Side	1		3	3	3							10	12.85±0.13	Seg. & Side +0.99±0.15	6.6

Since there are two independent factors concerned in the development of panicle type, the question arises as to whether there is a length factor linked with each factor for open panicle. Theoretically, half of the segregating F_3 families should give 15:1 ratios and half give 3:1 ratios for open versus side panicle. If length factors are linked with both panicle factors, those families segregating 15:1 should have longer grain than those segregating 3:1. The segregating families were classified, where possible, into two classes as to manner of segregation, and the mean length of grain determined. Thirty-five families segregating in an approximate 3:1 ratio gave a mean grain length of 13.64±0.06 millimeters. While 24 families segregating in a 15:1 manner had a mean length of 14.18±0.07 millimeters, a length equal to that of the homozygous open families. The difference in favor of the 15:1 families is 0.54±0.09. The odds against a difference as great as the one shown being due to chance are extremely high. From these data it would seem that two factors for grain length are linked, one with each of the two factors for panicle type.

Relation of Length of Grain and Awn Development

The data on the relation of grain length and awns in the F_2 generations grown in 1923 and 1924 are presented in the form of correlation surfaces in Tables 18 and 19, while the breeding behavior of the F_3 families for the relation of these characters is given in Table 20.

A study of the data presented in these tables leads to the assumption that in the F_2 generation there was a correlation between strong awns and long grain, as shown by the correlation ratio, which was of about the same value for 1923 and 1924. The awn classes

in the F_3 data are the same as presented in Table 13. In this case, the value for η is 0.469±0.043, and the data in the table shows that this relation is positive; the awned lines tending to have the longer grains.

TABLE 18.—Length of Grain and Awn Development of F_2 Generation of the Cross Sparrowbill with Victor and Reciprocal, Grown in 1923.

Awns on F_2 Plants	Length of Grain on F_2 Plants in Millimeters								Total Plants
	12	13	14	15	16	17	18	19	
0			4	4			1		9
1	2	7	13	23	5	1			51
2	1	8	15	29	30	9	1		93
3		5	35	50	69	24	1		184
4	1	1	11	42	45	29	1	2	132
5	1	1	10	16	46	32	9	1	116
Total	5	22	88	164	185	95	13	3	585

$\eta = 0.358 \pm \cancel{0.24}$ 0.024

TABLE 19.—Length of Grain and Awn Development of F_2 Generation of the Cross Sparrowbill with Victor and Reciprocal, Grown in 1924.

Awns on F_2 Plants	Length of Grain on F_2 Plants in Millimeters								Total Plants
	12	13	14	15	16	17	18	19	
0		2	2	1					5
1	8	8	8	3	3				30
2	5	8	15	3	1	1			33
3	3	14	23	17	8				65
4	3	44	61	28	12	2			150
5		15	37	45	26	6	0	1	130
Total	19	91	146	97	50	9	0	1	413

$\eta = 0.368 \pm \cancel{0.29}$ 0.029

TABLE 20.—Breeding Behavior of F_3 Families of the Cross Sparrowbill with Victor and Reciprocal for Length of Grain and Awn Development.

Classification of F_3 Lines for Awns	Mean Length of F_3 Families in Millimeters											Total
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	
Awnless	1				1							2
Awnless Dominant				1	2	2	1					6
Like F_2		3	11	13	21	16	10	5	1			80
Awns Dominant			4	3	10	9	16	4	5	1		52
Awned					1		4	1	2	1	1	10
Total	1	3	15	17	35	27	31	10	8	2	1	150

$\eta = 0.469 \pm \cancel{0.43}$ 0.043

TABLE 21.—Relation of Grain Color and Panicle Type in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

Year	Kind of Ratio	Black Open	White Open	Black Side	White Side	Total	X^2	P
1923	Obs'd	420.00	126.00	28.00	11.00	585		
	Cal'd	411.30	137.10	27.42	9.14	585	1.4734	.6929
1924	Obs'd	295.00	89.00	20.00	9.00	413		
	Cal'd	290.25	96.75	19.35	6.45	413	1.7285	.6345
Both	Obs'd	715.00	215.00	48.00	20.00	998		
Years	Cal'd	701.55	233.85	46.77	15.59	998	3.0569	.3176

Relation of Grain Color and Panicle Type

The relation of color of grain and panicle type is given for the F_2 plants in Table 21 and for the F_3 families in Table 22.

The data for F_2 indicate a very close fit to the calculated for a 45:15:3:1 ratio, assuming a two factor difference for panicle type and one for color. This tends to prove that the factor for color of grain and the factors for type of panicle are inherited independently.

The breeding behavior of the F_3 lines for color of grain and panicle type furnish more conclusive evidence that these factors are inherited independently, the observed ratio being very close to the calculated (P=0.9845).

TABLE 22.—Breeding Behavior for Color and Panicle Type of F_3 Families of the Cross Sparrowbill with Victor and Reciprocal, Grown in 1924.

Panicle Class	Color Class	Observed Numbers	Calculated Numbers
Open	Black	15	16.41
Open	Segregating	30	32.81
Open	White	20	16.41
Segregating	Black	18	18.75
Segregating	Segregating	37	37.50
Segregating	White	20	18.75
Side	Black	2	2.34
Side	Segregating	6	4.68
Side	White	2	2.34
Total		150	150

$X^2 = 1.7984 \quad P = .9845$

Although an attempt was made to select at random the F_2 plants to continue in F_3 it has been shown that too many side panicle plants were continued for a random selection. In the F_3 data presented here regarding the relation of panicle type and grain color no correction is attempted, and for this reason the value of P is probably slightly too high.

Relation of Grain Color and Awn Development

Data for the relation between grain color and awns in the F_2 hybrids of the Sparrowbill with Victor cross are presented in Table 33 of the appendix. In addition to the actual numbers observed in each awn class, the percentage of individuals in each class is given. It will be seen that among the plants with white grains the percentage of awns in the "0", "1", and "2" classes is higher than among plants with black grain, while in the "3" and "4" awn classes there is not so much difference, although the blacks are usually in excess in the "4" class. In the "5" awn class the whites fall off quite sharply. This would possibly indicate that the factors for black color and for awn development are linked.

To determine if the white and black grained plants did actually behave differently for awns, X^2 was computed on the percentage figures, using the black plants as the calculated and the whites as observed. It will be seen that for the 1923 data P is very low, while for 1924 the fit is very good. Combining the two years results $P = .2894$, or, more often than once out of four trials a worse result than the one observed would be expected due to chance. This fit is not at all bad, and the results indicate that if there is linkage it is not close.

The breeding behavior of the hundred and fifty F_3 families for grain color and awns is presented in Table 23. There is a marked tendency for the families homozygous for black grain to be awned, or partly awned, as in no case was there a homozygous black grained line breeding true for awnlessness. In the homozygous white lines, however, three families in forty-two were homozygous for awns, ten had awns dominant, although only two had awnlessness dominant and none were awnless. This again indicates that, for some reason, too few lines were found breeding true for awnlessness. If there is linkage between the factor for color and a factor for awns, which is doubtful, it must be considered as very loose.

TABLE 23.—Breeding Behavior for Color of Grain and Awns in F_3 Families of the Cross Sparrowbill with Victor and Reciprocal, Grown in 1924.

Color of Grain	Behavior for Awns					Total
	Awned	Awns Dominant	Like F_2	Awnless Dominant	Awnless	
Black	3	16	16			35
Seg.	4	26	37	4	2	73
White	3	10	27	2		42
Total	10	52	80	6	2	150

Relation of Panicle Type and Awn Development

There seems to be a close linkage between open panicles and awns, as the percentage of individuals with stronger awns is much higher in the open panicle plants than in the side types (see Table 34 of the appendix). Considering both F_2 families grown, 79 per cent of the open panicle plants had awns of class "3" or stronger, while only 57 per cent of the side plants were classed in this group. Of the open panicle plants 20 per cent had "0", "1", or "2" awns, while 43 per cent of the side panicle plants were classed with awns of class "2" or less. X^2 was computed for these data, using the open panicle group as the calculated and the side types as the observed. In all cases P is very low, indicating that there is little probability that the deviations observed are due to chance.

A study of the F_3 lines for panicle type and awns discloses a strong tendency for open panicle plants to be awned, or mostly awned, while in one case in sixty-five a line was homozygous open and awnless (see Table 24). No awned, side panicle type was found, although one line had awns dominant. From the F_2 and F_3 data it seems that the factors for awns and panicle type are linked. This linkage is not physiological, since open-panicled, awnless lines were recovered in F_3.

TABLE 24.—Breeding Behavior for Panicle Type and Awns in F_3 Families of the Cross Sparrowbill with Victor and Reciprocal, Grown in 1924.

Type of Panicle	Behavior for Awns					Total
	Awned	Awns Dominant	Like F_2	Awnless Dominant	Awnless	
Open	5	29	27	3	1	65
Seg.	5	22	46	2		75
Side		1	7	1	1	10
Total	10	52	80	6	2	150

DISCUSSION OF RESULTS

A study of inheritance was made in a cross between Sparrowbill and Victor oats. The characters studied were length of grain, color of grain, awns, and type of panicle. The Victor parent has long, black grain, strong, black twisted, geniculate awns, and open panicles; while the Sparrowbill parent has short, white grain, none or very few awns, and a side panicle. The cross was made reciprocally and in no case was there a difference in segregation in the cross or the reciprocal.

Grain length appeared to be a very stable size character. The segregation as obtained for grain length, based on the number of F_3 families which appeared to be homozygous, could be explained on a three factor basis, each factor when heterozygous having a greater effect than when homozygous, and the various factors interacting in a cumulative way. Black versus white grain was apparently dependent on a single factor pair. Open versus side panicle type appeared to be differentiated by two duplicate factors with open panicle dominant. The development of awns could not be explained on a single factor basis.

After determining the mode of inheritance of the individual characters, a study was made to determine any possible linkage in inheritance of the various characters. The study of the linkage of factors on the chromosome basis is of particular interest in relation to the mode of inheritance of size characters.

Considering the relation of grain length and color in F_2 it was found that there was practically no relation between these two characters, as no significant differences in grain length were observed between black and white plants. The F_3 families were grouped into three classes of grain, namely, homozygous black, homozygous white, and segregating for color. The mean length of grain of each of these groups was determined. In no case is there a significant difference between these means. Figure 1 presents graphically the mean length of grain of the F_3 families homozygous for white and for black grains. These facts seem to show that there is no linkage be-

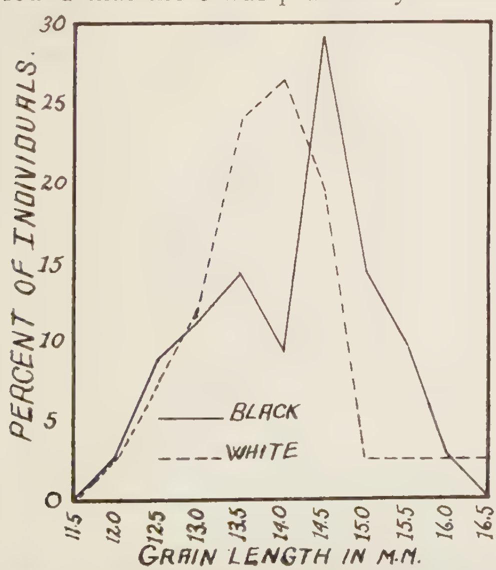


Fig. 1.—Relation of Grain Length and Grain Color in Individual F_3 Families, Homozygous for Black and White Grain. Sparrowbill with Victor and Reciprocal.

tween the factor for grain color and a factor or factors for grain length.

Considering the relation of panicle type and length of grain, the data for F_2 bring out the fact that in both years the F_2 open panicle plants had longer grain than the side panicle plants. The differences for 1923 and 1924 were respectively 0.69 ± 0.14 and 0.74 ± 0.14, with odds of 1,050:1 and more than 1,350:1 that differences as great as the ones shown are not due to chance. For the F_3 families the differences are more striking, the homozygous open families having a mean length of grain 1.27 ± 0.14 millimeters longer than the homozygous side panicle families. Figure 2 presents the data for F_3 in the form of a chart. In this chart the length of grain of the homozygous open and homozygous side families is compared, and also the length of grain in families segregating in a ratio of 15:1 and 3:1 for open and side panicles. The chart brings out the fact that the families segregating 15:1 had a grain length longer on the average than the families segregating 3:1. The mean length of grain for the families segregating in the 15:1 and 3:1 ratios respectively was 14.18 ± 0.07 and 13.64 ± 0.06. The chances that these values are significantly different are extremely high. These data indicate that probably a factor for grain length is linked with each of the factors for panicle type.

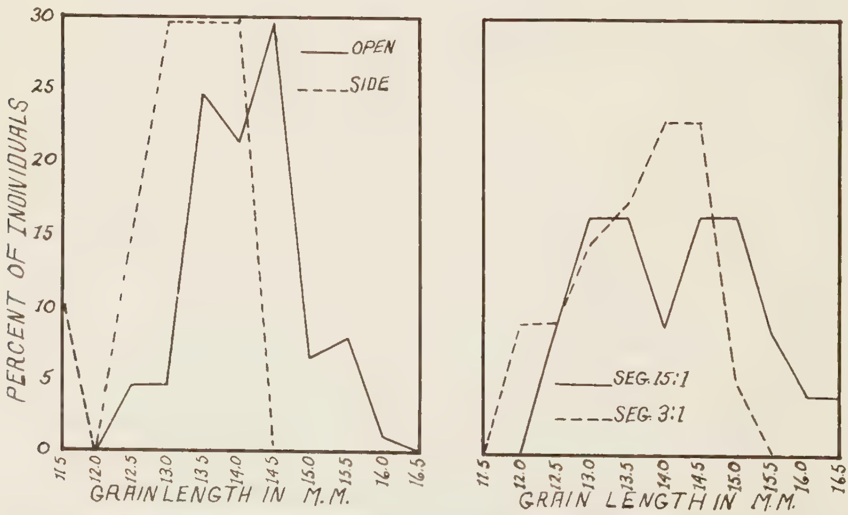


Fig. 2.—Relation of Grain Length and Panicle Type in Individual F_3 Families of the Cross Sparrowbill with Victor and Reciprocal. Left: Families Homozygous for Open and Side Panicles. Right: Families Segregating in Ratios of 15:1 or 3:1 for Open and Side Panicles.

Since it is shown that probably there is a factor for grain length linked with each of the two factors for panicle type, this would place a factor, or a group of factors for length of grain, in each of the two linkage groups which contain factors for panicle type. A study of the relation of panicle type and grain color in the F_2 data and in the F_3 breeding behavior shows that there was no relation between these characters. This would indicate that the factor for grain color is in a third linkage group.

A study of the relation of panicle type and awns indicates a rather close correlation between these two characters. In F_2 there was a strong tendency for the open panicle plants to be stronger awned than the side panicle plants, as is shown in Figure 3. The F_3 data brought out the fact that homozygous open panicle families were inclined to be fully awned like the Victor parent. One family was found, however, which was homozygous awnless and was breeding true for open panicle. Such a result proves that a cross-over took place, breaking the linkage between awns and open panicles. The homozygous side families on the other hand had fewer awns and showed a tendency to breed awnless, like the Sparrowbill parent. This suggests a linkage between at least one factor for awns and one of the factors for open panicles. One family breeding true for side panicle was classed as awns dominant, giving another indication of a crossover.

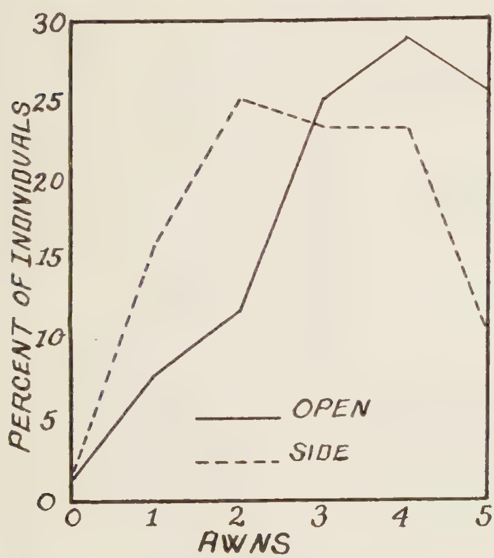


Fig. 3.—Relation of Panicle Type and Awn Development in F_2 Plants of the Cross Sparrowbill with Victor and Reciprocal Grown in 1923 and 1924.

If a factor for awns is linked with a factor for panicle type, there should be some indication of relation between grain length and awns, since it has been shown that there in a relation between panicle type and length of grain. The data presented indicate that such is the case; that a fully awned condition and long grains tend to be associated. This relation in the F_2 families grown in 1923, as expressed by the correlation ration, was $\eta = 0.358 \pm 0.024$, and in 1924,

$\eta = 0.368 \pm 0.029$. For the F_3 families the value of η was 0.469 ± 0.043 These values of η indicate a rather close relation between awns and length of grain. From this it may be assumed that in at least one of the linkage groups in which there is a factor for panicle type and a factor or group of factors for grain length there is also a factor or factors for awns.

The other relation studied was between awns and color of grain. The data are rather indefinite in F_2, since in 1923 there was an indication of linkage between black color and awns, while the probabilities of such a linkage in the 1924 material are rather small. Figure 4 presents the combined data for F_2, giving the percentage of black and white plants in the various awn classes. It is seen that there is little difference between the curves for black grain plants and the one for white plants, except that the line representing the white grain plants drops off sharply in the fully awned class. The F_3 data indicate, however, that the families homozygous for black grain tend to be heavier awned than the families homozygous for white grain. Only two homozygous awnless families were grown in F_3 and these were segregating for color. Of the homozygous white grain families three were classed as fully awned. These facts make it rather doubtful that there is a linkage between the factor for color and a factor for awns. If any linkage is assumed it must be considered to be very loose.

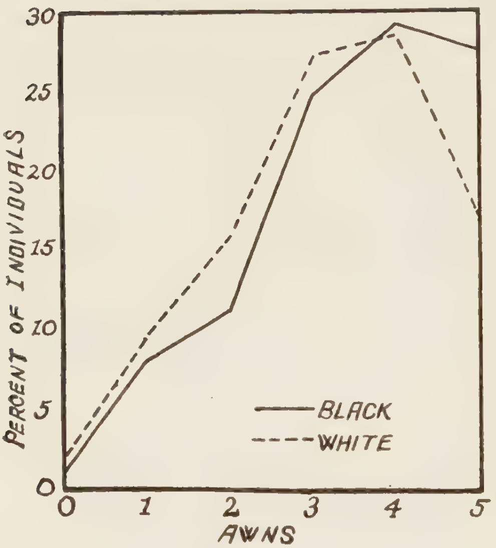


Fig. 4.—Relation of Color of Grain and Awn Development in F_2 Plants of the Cross Sparrowbill with Victor and Reciprocal Grown in 1923 and 1924.

SUMMARY

1.—A study was made of the inheritance of length of grain and other differential characters in a cross between Sparrowbill and Victor oats. The Victor parent had a mean length of the primary grain of 16.4 millimeters, black grain color, open panicle, and each primary grain carried a rather strong, black twisted, geniculate awn.

The Sparrowbill, on the other hand, had a mean grain length of 11.5 millimeters, white grain color, side panicle, and none or very few of the grains were awned.

2.—All of the primary grains from the leading panicle of 117 plants of Victor grown on good soil in 1923 were removed in order from the base to the tip of the panicle and measured for length. From these data it was found that a sample of ten grains selected from all parts of the panicle gave approximately as accurate a measure of grain length for the panicle as did all of the grains in the panicle. It was also shown that grains at the tip of the panicle were longer than those at the base. A sample of ten grains, selected at random from the leading panicle was used as a sample from which to determine the length of grain for each plant studied.

3.—Each parent was grown on good and poor soil in order to study the influence of soil condition on length of grain. It was found that poor soil did not greatly reduce grain length although height and yield of plant were greatly reduced. This brings out the fact that, while grain length is variable, it is less variable than such characters as plant yield and height.

4.—The parent varieties differed in grain length by about 4.9 millimeters. The F_1 was intermediate for length of grain, although tending to approach the length of Victor. The F_2 variability for grain length was much greater than for either parent, the range being from the length of one parent to the length of the other. In F_3 two families from a total of a hundred and fifty were recovered with a mean grain length as short as Sparrowbill, and four with a mean length as great as Victor. Between these two extremes were found lines apparently homozygous for grain of intermediate length. The results obtained can be explained satisfactorily by the assumption that the parents differ by at least three main factors or groups of factors for grain length.

5.—Color of grain was controlled by a single factor pair, black being dominate. Panicle type was controlled by two duplicate factors, one or both present in the dominant condition giving open panicles. Inheritance of awns was of a more complex nature and could not be explained by a single factor difference.

6.—It was found that there was no linkage between the factor for color of grain and any factors for length of grain. With each factor for panicle type is probably linked a factor, or group of factors, for grain length. At least one factor for awns is linked with a factor or factors for length of grain, and there was also linkage between

a factor for panicle type and one for awns, as would be expected since length of grain and panicle type are associated.

7.—It was demonstrated that color of grain and paincle type were not associated and there was little or no relation between color and awns. The data indicate three linkage groups, one containing a factor for color and possibly a factor for awns. A second group contains a factor for panicle type, together with a factor, or group of factors, for the characters length of grain and awns, respectively, while the third group contains a factor for panicle type and a factor or factors for grain length.

LITERATURE CITATIONS

CAPORN, A. ST. CLAIR
1918. AN ACCOUNT OF AN EXPERIMENT TO DETERMINE THE HEREDITY OF EARLY AND LATE RIPENING IN AN OAT CROSS. Jour. Genetics 7: 247-257.

EAST, E. M.
1916. STUDIES ON SIZE INHERITANCE IN NICOTIANA. Genetics 1: 164-176.

ETHRIDGE, W. C.
1916. A CLASSIFICATION OF THE VARIETIES OF CULTIVATED OATS. N. Y. Cornell Agr. Exp. Sta. Mem. 10.

FRASER, A. C.
1919. THE INHERITANCE OF THE WEAK AWN IN CERTAIN AVENA CROSSES AND ITS RELATION TO OTHER CHARCTERS OF THE OAT GRAIN. N. Y. Cornell Agr. Exp. Sta. Mem .23.

GAINES, E. F.
1917. INHERITANCE IN WHEAT, BARLEY, AND OAT HYBRIDS. Wash. Agr. Exp. Sta. Bul. 135.

GARBER, R. J.
1922. INHERITANCE AND YIELD WITH PARTICULAR REFERENCE TO RUST RESISTANCE AND PANICLE TYPE IN OATS. Minn. Agr. Exp. Sta. Tech. Bul. 7.

GRIFFEE, FRED
1925. CORRELATED INHERITANCE OF BOTANICAL CHARACTERS IN BARLEY AND MANNER OF REACTION TO HELMINTHOSPORIUM SATIVUM. Jour. Agr. Res. 30: 915-935.

HAYES, H. K. and GARBER, R. J.
1921. BREEDING CROP PLANTS. pp. 89-98. McGraw-Hill Book Company, New York.

LINDSTROM, E. W.
1924. A GENETIC LINKAGE BETWEEN SIZE AND COLOR FACTORS IN THE TOMATO. Science, N. S. 60: 182-183.

LOVE, H. H.
1924. A MODIFICATION OF STUDENT'S TABLE FOR USE IN INTERPRETING EXPERIMENTAL RESULTS. Jour. Amer. Soc. Agron. 16: 68-73.

-------------- and CRAIG, W. T.
1918-a. THE RELATION BETWEEN COLOR AND OTHER CHARACTERS IN CERTAIN AVENA CROSSES. Amer. Not. 52: 369-383.

1918-b. SMALL GRAIN INVESTIGATIONS. Jour. Heredity 9: 67-76.

LOVE, H. H. and FRASER, A. C.
1917. THE INHERITANCE OF THE WEAK AWN IN CERTAIN AVENA CROSSES. Amer. Nat. 51: 481-493.

NILSSON-EHLE, H.
1908. EINIGE ERGEBNISSE VON KREUZUNGEN BEI HAFER UND WEIZEN. Botan. Notiser, Lund., pp. 257-298.

1909. KREUZUNGSUNTERSUCHUNGEN AN HAFER UND WEIZEN. Lunds Univ. Arsskr. N. F. Afd. 2, Bd. 5, Rr. 2, pp. 122.

NORTON, J. B.
1907. NOTES ON BREEDING OATS. Amer. Breeders Asoc. 3: 280-285.

SAX, KARL
1923. THE ASSOCIATION OF SIZE DIFFERENCES WITH SEED-COAT PATTERN AND PIGMENTATION IN PHASEOLUS VULGARIA. Genetics 8: 552-560.

SURFACE, FRANK M.
1916. STUDIES ON OAT BREEDING. III. On the inheritance of certain glume characters in the cross Avena fatua x A. sativa var. Kherson. Genetics 1: 252-286.

WILSON, JOHN H.
1907. THE HYBRIDIZATION OF CEREALS. Jour. Agr. Sci. 2: 68-88.

WAKABAYASHI, S.
1921. A STUDY OF HYBRID OATS AVENA STERILIS X AVENA ORIENTALIS. Jour. Amer. Soc. Agron. 13: 259-266.

ZINN, JACOB and SURFACE, F. M.
1917. STUDIES ON OAT BREEDING. V. The F_1 and F_2 generation of a cross between a naked and a hulled oat. Jour. Agr. Research 10: 293-312.

APPENDIX

TABLE 25.—Frequency Distributions of Mean Length of Grain for Samples of 5, 10, 15, and All Grains From the Leading Panicle of Each Plant. Victor Parent Grown on Good Soil, 1923.

No. Grains in Sample	Plants with Mean Length of Grain in Millimeters of														Total	Mean	Standard Deviation	P. E. Single Determination
	15.8	16.1	16.4	16.7	17.0	17.3	17.6	17.9	18.2	18.5	18.8	19.1	19.4	19.7				
5	1	6	2	7	10	17	10	14	13	17	9	8	2	1	117	17.82±0.05	0.86±0.04	0.58
10	1	5	3	8	14	12	9	19	11	13	13	5	1	3	117	17.80±0.06	0.88±0.04	0.59
15	1	1	7	7	15	11	15	12	15	13	11	5	3	1	117	17.79±0.05	0.84±0.04	0.56
All	1	2	5	9	14	12	11	14	18	14	10	4	2	1	117	17.77±0.05	0.82±0.04	0.55

TABLE 26.—Progressive Differences in Mean Length of Grain, by Groups of Five, from the Base to the Tip of the Panicle. Victor Parent Grown on Good Soil, 1923.

Group No. (5 Grains per Group)	Number of Plants	Approximate Number of Grains on Leading Panicle	Mean Length of Grains in Millimeters
1	9	15	16.9±0.2
2	9	15	17.0±0.2
3	9	15	18.0±0.2
1	11	20	16.9±0.2
2	11	20	17.2±0.1
3	11	20	17.3±0.2
4	11	20	17.9±0.2
1	19	25	17.2±0.1
2	19	25	17.4±0.1
3	19	25	17.4±0.1
4	19	25	17.9±0.2
5	19	25	18.2±0.2
1	21	30	17.7±0.1
2	21	30	17.7±0.1
3	21	30	17.7±0.1
4	21	30	17.8±0.1
5	21	30	18.6±0.1
6	21	30	18.6±0.1
1	21	35	17.2±0.1
2	21	35	17.5±0.2
3	21	35	17.5±0.1
4	21	35	17.8±0.1
5	21	35	18.0±0.2
6	21	35	18.3±0.2
7	21	35	18.4±0.2
1	13	40	17.3±0.2
2	13	40	17.2±0.2
3	13	40	17.4±0.2
4	13	40	17.8±0.2
5	13	40	17.5±0.1
6	13	40	17.9±0.2
7	13	40	18.4±0.2
8	13	40	18.6±0.2
1	11	45	17.4±0.2
2	11	45	17.6±0.2
3	11	45	17.7±0.1
4	11	45	17.7±0.1
5	11	45	17.7±0.2
6	11	45	17.9±0.2
7	11	45	18.1±0.2
8	11	45	18.2±0.2
9	11	45	18.3±0.2
1	9	50	17.3±0.2
2	9	50	17.6±0.2
3	9	50	17.4±0.2
4	9	50	17.7±0.2
5	9	50	17.9±0.2
6	9	50	17.8±0.2
7	9	50	17.7±0.3
8	9	50	18.0±0.3
9	9	50	18.0±0.3
10	9	50	18.0±0.3

TABLE 27.—Length of Grain of Sparrowbill Parent Grown in Various Plots, 1924.

1924 Row Number	Grain Lentgh of Plants in Millimeters				Total No. Plants	Mean Length of Grain in Milli-meters	Standard Deviation	Coefficient of Variability
	10	11	12	13				
937-38S		5	24		29	11.83±0.05	0.38	3.21±0.20
943-44S		5	15	2	22	11.86±0.08	.55	4.64±0.33
953-54S		8	18		26	11.69±0.06	.46	3.93±0.26
963-64S	2	24	15		41	11.32±0.06	.56	4.95±0.26
973-74S	2	18	18		38	11.42±0.07	.59	5.17±0.28
983-84S		24	15		39	11.39±0.05	.49	4.30±0.23
997-98S		21	18		39	11.46±0.05	.50	4.36±0.24
1011-12S		25	11		36	11.31±0.05	.46	4.07±0.23
1025-26S		13	25		38	11.66±0.05	.47	4.03±0.22
1039-40S		8	25		33	11.76±0.05	.43	3.66±0.21
1053-54S		17	16	1	34	11.53±0.06	.55	4.77±0.28
1067-68S	2	28	12	1	43	11.28±0.06	.58	5.14±0.26
1081-82S		24	12		36	11.33±0.05	.47	4.15±0.23
1095-96S	1	30	7		38	11.16±0.05	.43	3.85±0.21
1109-1110S	2	21	11		34	11.27±0.07	.56	4.97±0.29
1123-24S		22	19		41	11.46±0.05	.50	4.36±0.23
1137-38S		19	15		34	11.44±0.06	.50	4.37±0.25
1151-52S		4	24	1	29	11.90±0.05	.40	3.36±0.21
1165-66S	2	20	11		33	11.27±0.07	.57	5.06±0.30
1179-80S	7	20	11		38	11.11±0.07	.68	6,12±0.33
1193-94S	1	12	23	1	37	11.65±0.06	.58	4.98±0.28
1207-08S	1	15	22		38	11.55±0.06	.55	4.76±0.26
1221-22S	1	14	21		36	11.56±0.06	.55	4.76±0.27
1235-36S	2	14	19		35	11.49±0.07	.60	5.22±0.30
1249-50S		13	18		31	11.58±0.06	.49	4.23±0.26
1263-64S	2	18	21	1	42	11.50±0.07	.63	5.48±0.29
1277-78S	1	23	17		41	11.39±0.06	.54	4.74±0.25
1291-92S	1	14	24		39	11.59±0.06	.54	4.66±0.25
1305-06S		20	20		40	11.50±0.05	.50	4.35±0.23
1319-20S	2	29	9	1	41	11.22±0.06	.56	4.99±0.26
1331-32S		20	16		36	11.44±0.06	.50	4.37±0.25
1347-48S		15	18	1	34	11.59±0.06	.55	4.75±0.27
1361-62S		13	21	1	35	11.66±0.06	.53	4.55±0.26
1375-76S		13	20	1	34	11.65±0.06	.54	4.64±0.27
1389-90S		6	26	1	33	11.85±0.05	.44	3.71±0.22
1403-04S		25	12		37	11.32±0.05	.47	4.15±0.23

TABLE 28.—Length of Grain of Victor Parent Grown in Various Plots, 1924.

1924 Row Number	Grain Lentgh of Plants in Millimeters					Total No. Plants	Mean Length of Grain in Millimeters	Standard Deviation	Coefficient of Variability
	15	16	17	18	19				
935-36S	1	23	9			33	16.24±0.06	0.49	3.02±0.18
941-42S	1	18	7	3		29	16.41±0.09	.72	4.39±0.27
951-52S	5	26	3			34	15.94±0.06	.48	3.01±0.17
961-62S	8	18	7			33	15.97±0.08	.67	4.20±0.25
971-72S	3	21	16			40	16.33±0.07	.61	3.74±0.20
981-82S		18	21	1		40	16.58±0.06	.54	3.26±0.17
995-96S	1	14	18	4		37	16.68±0.08	.70	4.20±0.23
1009-10S	2	27	7			36	16.14±0.05	.48	2.97±0.17
1023-24S	2	23	8			33	16.18±0.06	.52	3.21±0.19
1037-38S		19	11			30	16.37±0.06	.48	2.93±0.18
1051-52S		16	14	1		31	16.52±0.07	.56	3.39±0.21
1065-66S		28	10			38	16.26±0.05	.44	2.71±0.15
1079-80S		15	22	1		38	16.63±0.06	.54	3.25±0.18
1093-94S	1	9	24	2		36	16.75±0.07	.60	3.58±0.20
1107-08S	1	16	23	2		42	16.62±0.06	.62	3.73±0.19
1121-22S		13	22	2		37	16.70±0.06	.56	3.35±0.19
1135-36S	1	20	14	1		36	16.42±0.07	.60	3.65±0.21
1149-50S	1	15	6	1		23	16.30±0.09	.62	3.80±0.27
1163-64S	3	26	10	1		40	16.23±0.06	.61	3.76±0.20
1177-78S	1	18	13			32	16.38±0.07	.55	3.36±0.20
1191-92S	2	19	11	1		33	16.33±0.08	.64	3.92±0.23
1205-06S	4	26	14	1		45	16.27±0.07	.65	4.00±0.20
1219-20S	1	13	20	4		38	16.71±0.08	.69	4.13±0.23
1233-34S		28	13	1		42	16.36±0.06	.53	3.24±0.17
1247-48S	3	26	4			33	16.03±0.05	.46	2,87±0.17
1261-62S	1	32	2			35	16.03±0.03	.29	1.81±0.10
1275-76S		33	6	1		40	16.20±0.05	.46	2.84±0.15
1289-90S		25	13	1		39	16.39±0.06	.54	3.29±0.18
1303-04S	3	20	9	1		33	16.24±0.08	.65	4.00±0.23
1317-18S	3	29	5			37	16.05±0.05	.46	2.86±0.16
1329-30S	2	19	13			34	16.32±0.07	.58	3.55±0.21
1345-46S	2	14	14	2	1	33	16.58±0.10	.82	4.95±0.29
1359-60S	2	23	15			40	16.33±0.06	.57	3.49±0.19
1373-74S	2	16	18			36	16.44±0.07	.60	3.65±0.21
1387-88S		25	11	1		37	16.35±0.06	.53	3.24±0.18
1401-02S		16	22			38	16.58±0.05	.49	2.96±0.16

TABLE 29.—Breeding Behavior for Length of Grain of the F_3 Families of the Cross Victor with Sparrowbill, Grown in 1924.

1924 Row Number	N. H. N.	Length Grain on Parent Plant	Number of Plants with Grain Length in Millimeters									Total Number Plants	Mean	Coefficient of Variability
			10	11	12	13	14	15	16	17	18			
1195-96S	21-1-1	14.8			3	28	10					41	13.17±0.11	4.10±0.22
1197-98S	-2	15.9				1	4	7	7	5		24	15.46±0.15	7.24±0.50
1199-1200S	-3	16.3			8	19	9	4				40	13.23±0.09	6.65±0.35
1201-02S	-4	15.4			1	12	3	1	1			18	13.39±0.14	6.65±0.53
1203-04S	-5	12.9	5	17	12	1						35	11.26±0.11	6.48±0.37
1209-10S	-6	15.3			5	10	20	2				37	13.51±0.09	5.92±0.33
1211-12S	-7	15.7		3	14	13	3					33	12.49±0.09	6.24±0.37
1213-14S	-8	15.9			1	11	9	5				26	13.69±0.11	5.99±0.40
1215-16S	-9	14.8			2	8	11	7	2			30	13.97±0.12	7.30±0.45
1217-18S	-10	13.8	1	1	15	7	4					28	12.43±0.12	7.24±0.46
1223-24S	-11	15.4		2	9	14	6	3				34	12.97±0.12	7.78±0.45
1225-26S	-12	15.4			5	8	12	10	2			37	13.89±0.12	7.99±0.44
1227-28S	-13	13.9			13	19	4					36	12.75±0.07	5.02±0.28
1229-30S	-14	15.7			5	9	12	3	1			30	13.52±0.12	7.32±0.45
1231-32S	-15	16.6				2	9	6	14	2		33	15.15±0.13	7.13±0.42
1237-38S	-16	17.2			1	3	15	16	3			38	14.45±0.09	5.88±0.32
1239-40S	-17	15.2		4	14	10	4					32	12.44±0.10	6.91±0.41
1241-42S	-18	16.1				6	15	7	2	1		31	14.26±0.12	6.66±0.40
1243-44S	-19	15.5				10	8	6				24	13.83±0.11	5.78±0.56
1245-46S	-20	15.6			4	25	5	1				35	13.09±0.07	4.58±0.26
1251-52S	-21	16.8				3	9	15	1			28	14.50±0.09	5.03±0.32
1253-54S	-23	16.7			1	7	12	12	3			35	14.26±0.11	6.80±0.39
1255-56S	-24	15.7		1	2	7	14	10	2			36	14.00±0.12	7.71±0.43
1257-58S	-25	15.6			1	4	9	8	1			23	14.17±0.13	6.49±0.46
1259-60S	-26	16.5			5	11	10	2				28	13.32±0.11	6.38±0.41
1265-66S	-27	15.6			1	6	21	13	1			42	14.17±0.08	5.50±0.29
1267-68S	-28	15.0		1	8	17	7					33	12.91±0.09	5.89±0.35
1269-70S	-29	14.6		2	17	16	3					38	12.53±0.08	5.75±0.31
1271-72S	-30	16.3			3	6	14	3	2			28	13.82±0.13	7.24±0.46
1273-74S	-31	14.8		1	5	9	19	5				39	13.56±0.11	7.08±0.38
1279-80S	-32	18.6				2	1	11	16	3		33	15.52±0.11	5.99±0.35
1281-82S	-33	15.5			2	14	15	1				32	13.47±0.08	4.90±0.29
1283-84S	-34	17.7					5	8	17	2		32	15.50±0.10	5.35±0.32
1285-86S	-35	15.8				6	12	11	3			32	14.34±0.11	6.21±0.37
1287-88S	-36	13.7		1	1	7	20	3	1			33	13.79±0.10	6.38±0.37

1293-94S	-37	17.2					3	9	14			26	15.42±0.09	4.34±0.29
1295-96S	-38	14.7			1	11	15	4				31	13.71±0.09	5.32±0.32
1297-98S	-39	13.7		1	11	17	7					36	12.83±0.09	5.92±0.33
1299-1300S	-40	17.8						3	14	8	2	27	16.33±0.10	4.72±0.31
1301-02S	-41	14.9		1	12	16	4					33	12.70±0.08	5.67±0.33
1307-08S	-42	14.9			1	9	12	3				25	13.68±0.10	5.34±0.36
1309-10S	-43	14.7		14	20	3						38	12.66±0.07	5.21±0.29
1311-12S	-44	16.8			1	5	15	8	2			31	14.16±0.11	6.21±0.38
1313-14S	-45	17.7			4	12	13	2				31	13.42±0.10	5.89±0.36
1315-16S	-46	14.9			7	22	4					33	12.91±0.07	4.42±0.26
1321-22S	-48	15.9				10	16	7				33	13.91±0.08	5.10±0.30
1323-24S	-49	17.3				1	2	10	15	6		34	15.68±0.11	5.93±0.34
1325-26S	-50	16.3			1	3	10	14	6			34	14.62±0.11	6.63±0.38
1327-28S	-51	14.8			4	8	15	6				33	13.70±0.11	6.57±0.39
1333-34S	-52	16.8				4	11	12	11			38	14.79±0.11	6.63±0.36
1335-36S	-53	15.6			2	9	15	4	1			31	13.77±0.11	6.32±0.38
1337-38S	-54	16.4				9	17	3				29	13.79±0.08	4.42±0.28
1339-40S	-55	16.1			5	13	6	4	1			26	13.41±0.13	7.76±0.49
1341-42S	-56	14.6			3	10	14	3				30	13.57±0.10	5.90±0.36
1343-44S	-47	13.7			5	10	10	1	1			27	13.37±0.12	7.11±0.46
1349-50S	-57	16.1		1	5	18	9	3	1			37	13.30±0.11	7.37±0.41
1351-52S	-58	15.7		4	13	17	2					36	13.53±0.09	5.62±0.32
1353-54S	-59	16.8			1	10	15	5	3			34	13.97±0.11	6.80±0.39
1355-56S	-60	16.3		1	3	11	17	6	2			40	13.75±0.11	7.56±0.40
1357-58S	-61	18.5				2	18	12	5			37	14.54±0.09	5.43±0.30
1363-64S	-62	16.6				3	11	12	3	1		30	14.60±0.11	6.30±0.39
1365-66S	-63	17.1			3	6	9	11	5			34	14.29±0.13	8.19±0.44
1367-68S	-64	15.5			4	9	6	1				20	13.20±0.12	6.14±0.46
1369-70S	-65	16.2				6	13	9	2			30	14.23±0.10	5.90±0.36
1371-72S	-66	14.7		1	2	11	8	4				26	13.46±0.13	7.21±0.48
1377-78S	-67	16.1			2	19	12	3				36	13.44±0.08	5.43±0.31
1379-80S	-68	13.4	2	9	16	11	1					39	12.00±0.10	7.58±0.41
1381-82S	-69	16.1			4	13	11	4				32	13.47±0.10	6.46±0.39
1383-84S	-70	15.1				8	14	1				23	13.70±0.08	4.01±0.28
1385-86S	-71	15.8				8	17	7	2			34	14.09±0.11	5.82±0.40
1391-92S	-72	15.0			5	11	13	2	2			33	13.55±0.12	7.53±0.44
1393-94S	-73	16.0			1	11	13	4	1			30	13.77±0.10	6.10±0.38
1395-96S	-74	15.4			4	14	9	1		1		29	13.38±0.12	7.47±0.47
1397-98S	-75	16.0						6	24	7	3	40	16.18±0.08	4.76±0.25
1399-1400S	-76	18.0			1	1	11	22	6			41	14.76±0.09	5.56±0.29

TABLE 30.—Breeding Behavior for Length of Grain of the F_3 Families of the Cross Sparrowbill with Victor, Grown in 1924.

1924 Row Number	N. H. N.	Length Grain on Parent Plant	Number of Plants with Grain Length in Millimeters									Total Number of Plants	Mean	Coefficient of Variability
			10	11	12	13	14	15	16	17	18			
985-86S	20-3-1	17.1				10	26	5				41	13.88±0.06	4.25±0.22
987-88S	-2	15.0			8	10	6	6				27	13.15±0.13	7.38±0.48
989-90S	-3	14.4		1	12	21	3					37	12.70±0.07	5.12±0.28
991-92S	-4	14.9		3	14	14	3					34	12.50±0.09	6.24±0.36
993-94S	-5	15.5			2	5	12		1			20	13.65±0.13	6.23±0.47
999-1000S	-6	15.5			14	19	8	1				42	12.91±0.08	6.04±0.31
1001-02S	-7	16.4				1	14	9	1	2		27	14.59±0.12	6.24±0.41
1003-04S	-8	16.7			1	2	13	16	2	1		35	14.54±0.10	6.26±0.36
1005-06S	-9	16.3		1	2	10	11	12				36	13.86±0.12	7.43±0.42
1007-08S	-10	16.3			1	3	14	5	1			24	14.08±0.11	5.75±0.40
1013-14S	-11	15.1			3	8	26	4				41	13.76±0.08	5.31±0.28
1015-16S	-12	15.9			1	3	11	12	5	3		35	14.74±0.13	7.87±0.45
1017-18S	-13	17.0			1	3	11	16	4			35	14.54±0.10	6.26±0.36
1019-20S	-14	15.0			4	7	17	6				34	13.74±0.10	6.48±0.37
1021-22S	-15	14.2		4	18	13	1	1				37	12.32±0.09	6.82±0.38
1027-28S	-16	14.9		7	14	12	5					38	12.40±0.10	7.50±0.41
1029-30S	-17	16.1				1	6	15	4			26	14.85±0.09	4.85±0.32
1031-32S	-18	17.5				5	13	9	5	3		35	14.66±0.13	7.84±0.45
1033-34S	-19	15.1			4	14	20	1				39	13.46±0.08	5.27±0.28
1035-36S	-20	15.5		4	13	11	2					30	12.37±0.10	6.47±0.40
1041-42S	-21	15.9				2	13	6	1			22	14.27±0.10	4.84±0.35
1043-44S	-22	17.0					1	15	10			26	15.35±0.07	3.53±0.24
1045-46S	-23	17.1					1	1	17	5	1	25	16.16±0.09	4.08±0.28
1047-48S	-24	16.2			1	1	6	3				11	14.00±0.17	6.07±0.62
1049-50S	-25	15.2					7	12	6			25	14.96±0.10	4.81±0.32
1055-56S	-26	14.0		4	10	15	7	1				37	12.76±0.11	7.60±0.42
1057-58S	-27	13.7		5	13	11	9					38	12.63±0.11	7.76±0.42
1059-60S	-28	12.9	1	2	6	2	1					12	12.00±0.19	8.33±0.81
1061-62S	-29	15.9				3	13	18	4	1		39	14.67±0.09	5.86±0.32
1062-64S	-30	15.3			3	16	11	3				33	13.42±0.09	5.81±0.34
1069-70S	-31	17.7				1	12	6	7	1		27	14.82±0.13	6.61±0.43
1071-72S	-32	17.7			2	2	13	7	4			28	14.32±0.13	7.26±0.46
1073-74S	-33	15.6			1	8	19	11	2			41	14.12±0.09	6.09±0.32
1075-76S	-34	16.8			2	14	11	11				38	13.82±0.10	6.59±0.36
1077-78S	-35	15.1		4	12	14	6	1				37	12.68±0.11	7.57±0.42

1083-84S	-36	16.7			1	2	18	14	5	1		41	14.56±0.10	6.46±0.34
1085-86S	-37	15.5				2	15	5				22	14.14±0.06	3.18±0.23
1087-88S	-38	16.4			5	17	6					28	13.04±0.08	4.83±0.31
1089-90S	-39	16.4				2	14	6	3	1	1	27	14.63±0.15	7.72±0.50
1091-92S	-40	14.8			3	18	11	2				34	13.35±0.08	5.39±0.31
1097-98S	-41	16.7				8	8	10	3			29	14.28±0.12	6.86±0.43
1099-1100S	-42	16.1				3	10	10	12	2		37	15.00±0.12	7.13±0.40
1101-02S	-43	16.0		2	4	13	14	5				38	13.42±0.11	7.60±0.42
1103-04S	-44	16.5			1	2	11	11	3	6		23	14.48±0.15	7.60±0.53
1105-06S	-45	16.3			1	6	4	14	3			28	14.43±0.13	7.21±0.46
1111-12S	-46	16.1		1	1	6	14	10	6	1		39	14.36±0.13	8.43±0.46
1113-14S	-47	14.1		1	11	20	5					37	12.78±0.08	5.48±0.30
1115-16S	-48	16.1	1	1	16	12						37	13.00±0.10	7.15±0.40
1117-18S	-49	17.3			1	5	22	7	4	1		40	14.28±0.10	6.79±0.36
1119-20S	-50	15.2			2	11	11	9	4			37	14.05±0.12	7.76±0.43
1125-26S	-51	15.9					11	12	4			27	14.72±0.09	4.76±0.31
1127-28S	-52	14.9		1	6	12	12	3	1			35	13.37±0.12	7.86±0.45
1129-30S	-53	15.1				2	28	15				45	14.29±0.05	3.78±0.19
1131-32S	-54	15.1				3	4	17	10	2		36	15.11±0.11	6.42±0.36
1133-34S	-55	14.2		1	11	23	1					36	12.67±0.06	4.58±0.26
1139-40S	-56	15.3				2	5	12	6			25	14.88±0.12	5.78±0.39
1141-42S	-57	16.5				1	8	10	4			23	14.74±0.11	5.36±0.28
1143-44S	-58	17.0					1	4	4		1	10	15.60±0.22	6.54±0.70
1145-46S	-59	13.5			4	16	5					25	13.04±0.08	4.60±0.31
1147-48S	-60	14.9			5	17	6					28	13.04±0.08	4.83±0.31
1153-54S	-61	16.0			3	14	14	1				32	13.41±0.08	5.22±0.31
1155-56S	-62	15.1				8	12	14	5			39	14.41±0.10	6.59±0.36
1157-58S	-63	14.7			1	12	12	7	1			33	13.85±0.10	6.43±0.38
1159-60S	-64	14.9			3	15	14	10				42	13.74±0.09	6.55±0.34
1161-62S	-65	16.3			1	8	12	9	5			35	14.26±0.12	7.36±0.42
1167-68S	-66	16.9				5	21	12	2			40	14.28±0.08	5.18±0.28
1169-70S	-67	17.3			1	3	15	10	4			33	14.39±0.11	6.39±0.38
1171-72S	-68	17.2				5	17	6	1			29	14.10±0.09	5.04±0.32
1173-74S	-69	14.0		15	16	12						43	11.93±0.08	6.62±0.34
1175-76S	-70	16.2			2	14	14	4	1			35	13.66±0.10	6.30±0.36
1181-82S	-71	14.9		7	8	11	7	5				38	12.87±0.14	9.95±0.54
1183-84S	-72	16.2			3	6	17	1				27	13.59±0.10	5.37±0.35
1185-86S	-73	14.6			3	13	14	6				36	13.64±0.10	6.30±0.35
1187-88S	-74	16.9				1	5	22	7	1		36	15.06±0.08	4.91±0.28
1189-90S	-75	16.4				1	5	8	13	4		31	15.45±0.12	6.54±0.40

TABLE 31.—Data on Breeding Behavior of F_3 Families of the Cross Victor with Sparrowbill for Color of Grain, Awns, and Panicle Type, Grown in 1924.

1924 Row Number	N. H. N.	Grain Color of F_2 Plant	No. Plants in F_3 With Grain		Panicle Type of F_2 Plants	Number Plants in F_3 With Panicle		Awn Development of F_2 Plant	No. Plants in F_3 with Awn Development						Total No. Plants
			Black	White		Open	Side		0	1	2	3	4	5	
1195-96S	21-1-1	W		41	S		41	1	4	13	7	14	3		41
1197-98S	-2	B	19	5	S	7	17	4		2	3	11	8		24
1199-1200S	-3	B	29	11	S	8	32	4		1		1	15	23	40
1201-02S	-4	B	14	4	S		18	1	7	8	3				18
1203-04S	-5	B	26	9	S		35	1	29	3	3				35
1209-10S	-6	B	30	7	S		37	2	11	4	6	10	5	1	37
1211-12S	-7	B	33		S		33	4	1	1	1	4	15	11	33
1213-14S	-8	B	21	5	S		26	2	3	6	2	9	5	1	26
1215-16S	-9	B	30		S	25	5	3	1		1	6	11	11	30
1217-18S	-10	B	24	4	S		28	2	5	6	5	4	7	1	28
1223-24S	-11	W		34	0	18	16	3	14	13	4	1	2		34
1225-26S	-12	W		37	0	37		3	2	5	6	8	7	9	37
1227-28S	-13	B	36		0	25	11	3	2	2	9	15	7	1	36
1229-30S	-14	W		30	0	30		4				1	16	13	30
1231-32S	-15	W		33	0	33		5			1	1	8	23	33
1237-38S	-16	W		38	0	32	6	4					5	33	38
1239-40S	-17	B	23	9	0	26	6	1	6	10	3	9	4		32
1241-42S	-18	B	31		0	28	3	3		3		3	14	11	31
1243-44S	-19	B	24		0	13	11	2		1		6	14	3	24
1245-46S	-20	B	27	8	0	32	3	3	1	1	2	14	17		35
1251-52S	-21	B	17	11	0	22	6	4				3	3	22	28
1253-54S	-23	B	25	10	0	35		3	3	12	7	7	5	1	35
1255-56S	-24	B	26	10	0	36		3	1	1	1	4	20	9	36
1257-58S	-25	B	21	2	0	23		5		1	3	4	9	6	23
1259-60S	-26	W		28	0	26	2	3	2	11	4	5	5	1	28
1265-66S	-27	B	42		0	34	8	3	6	7	4	9	14	2	42
1267-68S	-28	W		33	0	26	7	1	11	16	3	2	1		33
1269-70S	-29	W		28	0	36	2	2	4	4	10	6	8	6	38
1271-72S	-30	W		28	0	28		3		3	4	6	6	9	28
1273-74S	-31	B	34	5	0	39		4		1	1	4	20	13	39
1279-80S	-32	B	27	6	0	31	2	5			3		15	15	33
1281-82S	-33	B	21	11	0	22	10	1	5	8	5	3	7	4	32
1283-84S	-34	B	32		0	32		5		1		2	11	18	32
1285-86S	-35	B	27	5	0	32		1	5	13	9	5			32
1287-88S	-36	B	26	7	0	33		3	2	6	4	10	8	3	33

1293-94S	-37	B		27	0	26		4			1	1	5	19	26
1295-96S	-38	B	23	8	0	31		0	20	9	2				31
1297-98S	-39	B	36		0	36		1	12	10	7	3	3	1	36
1299-1300S	-40	B		27	0	26	1	5					4	23	27
1301-02S	-41	W		33	0	33		2	1	5	4	10	9	4	33
1307-08S	-42	B	19	6	0	25		4					15	10	25
1309-10S	-43	B	25	13	0	38		3				5	19	14	38
1311-12S	-44	B	23	8	0	31		5			1		5	25	31
1313-14S	-45	B	20	11	0	31		3	2	2	1	4	15	7	31
1315-16S	-46	B	33		0	19	14	3		2	9	7	13	2	33
1321-22S	-48	B	21	12	0	29	4	3		1	2	4	17	9	33
1323-24S	-49	W		34	0	33	1	4		3	1	3	14	13	34
1325-26S	-50	W		34	0	34		3		1			15	18	34
1327-28S	-51	B	21	12	0	33		3	6	15	6	5		1	33
1333-34S	-52	B	38		0	24	14	3		2	4	8	16	8	38
1335-36S	-53	B	27	4	0	31		2	6	6	7	9	2	1	31
1337-38S	-54	B	24	5	0	27	2	5			1	3	8	17	29
1339-40S	-55	W		29	0	25	4	3			3	4	16	6	29
1341-42S	-56	B	24	6	0	30		4	4	3	6	9	6	2	30
1343-44S	-56	B		27	0	27		3	1	4	5	5	8	4	27
1349-50S	-57	B	27	10	0	35	2	3			1	5	23	4	37
1351-52S	-58	B	36		0	36		4		1	1	9	18	7	36
1353-54S	-59	W		34	0	21	13	4				2	11	21	34
1355-56S	-60	B	40		0	40		4				8	18	14	40
1357-58S	-61	B	23	14	0	37		5		1		2	13	21	37
1363-64S	-62	W		30	0	24	6	3	8	6	4	7	4	1	30
1365-66S	-63	B	34		0	34		3	1	2	7	8	9	7	34
1367-68S	-64	B	16	4	0	20		2		2		4	10	4	20
1369-70S	-65	B	23	7	0	24	6	3				3	12	15	30
1371-72S	-66	B	16	10	0	26		4		1		3	6	16	26
1377-78S	-67	B	26	10	0	26	10	2	9	9	11	1	5	1	36
1379-80S	-68	B	28	11	0	32	7	3	1	5	6	7	10	10	39
1381-82S	-69	B	28	4	0	18	14	3		1	3	5	16	7	32
1383-84S	-70	B	14	9	0	16	7	1		1	5	9	7	1	23
1385-86S	-71	W		34	0	34		4	1	3	2	9	12	7	34
1391-92S	-72	W		33	0	29	4	3	1	2	5	4	14	7	33
1393-94S	-73	W		30	0	30		2	1	10	6	3	6	4	30
1395-96S	-74	B	22	7	0	26	3	2	1	5	2	6	10	5	29
1397-98S	-75	W		40	0	40		4					2	38	40
1399-1400S	-76	B	41		0	38	3	4	1	2	3	6	17	12	41

TABLE 32.—Data on Breeding Behavior of F_3 Families of the Cross Sparrowbill with Victor for Color of Grain, Awns, and Panicle Type, Grown in 1924.

1924 Row Number	N. H. N.	Grain Color of F_2 Plants	No. Plants in F_3 With Grain		Panicle Type of Plants	Number Plants in F_3 With Panicle		Awn Development of F_2 Plants	No. Plants in F_3 with Awn Development						Total No. Plants
			Black	White		Open	Side		0	1	2	3	4	5	
985-86S	20-3-1	W		41	S	22	19	3	5	11	7	14	3	1	41
987-88S	-2	B	25	2	S		27	1	4	7	4	11	1		27
989-90S	-3	B	37		S		37	1	7	3	5	13	7	2	37
991-92S	-4	B	21	13	S	6	28	3	1	1	1	5	12	14	34
993-94S	-5	B	15	5	S	7	13	2	5	3	3	5	4		20
999-1000S	-6	W		42	S		42	2	21	14	4	2	1		42
1001-02S	-7	B	21	6	0	27		4	1	1	1	5	6	13	27
1003-04S	-8	B	25	10	0	35		5					14	21	35
1005-06S	-9	B	26	10	0	36		5			1	1	14	20	36
1007-08S	-10	W		24	0	9	15	2	2	3	2	7	8	2	24
1013-14S	-11	W		24	0	41		1	14	13	9	4	1		41
1015-16S	-12	B	35		0	35		5	1		3	3	9	19	35
1017-18S	-13	B	24	11	0	33	2	4		1		2	13	19	35
1019-20S	-14	B	24	10	0	26	8	3	7	9	4	9	5		34
1021-22S	-15	B	26	11	0	32	5	3	1	10	6	7	6	7	37
1027-28S	-16	B	27	11	0	21	17	3		4	5	10	14	5	38
1029-30S	-17	B	26		0	21	5	2			4	10	7	5	26
1031-32S	-18	B	29	6	0	31	4	3	1	4	6	8	12	4	35
1033-34S	-19	B		39	0	39		3		7	5	9	9	9	39
1035-36S	-20	B	22	8	0	20	10	4			1	1	17	11	30
1041-42S	-21	B	15	7	0	19	3	3			1	7	8	6	22
1043-44S	-22	B	26		0	26		5					4	22	26
1045-46S	-23	B	25		0	23	2	4					3	22	25
1047-48S	-24	B	10	1	0	8	3	5	1				4	6	11
1049-50S	-25	B	22	3	0	25		4	1		1	2	6	15	25
1055-56S	-26	B	30	7	0	37		3			1	5	10	21	37
1057-58S	-27	W		38	0	21	17	4	2	2	9	11	11	3	38
1059-60S	-28	B	12		S	7	5	4		1		2	4	5	12
1061-62S	-29	B	39		0	39		4				2	12	25	39
1063-64S	-30	W		33	0	13	20	2	2	5	4	10	7	5	33
1069-70S	-31	B	19	8	0	26	1	3	6	3	1	4	7	6	27
1071-72S	-32	B	22	6	0	28		5				1	4	23	28
1073-74S	-33	B	31	10	0	36	5	3	1	3	7	16	10	4	41
1075-76S	-34	W		38	0	35	3	2	2	11	5	13	5	2	38
1077-78S	-35	B	28	9	0	34	3	3	3	2	9	10	5	8	37

1083-84S	**-36**	**B**	**29**	**12**	**0**	**41**		**3**		**2**	**5**	**14**	**14**	**6**	**41**
1085-86S	-37	W		22	0	22		1	1	8	3	7	1	2	22
1087-88S	-38	B	28		0	19	9	4	1	1	3	2	10	11	28
1089-90S	-39	B	27		0	27		3		2	4	2	11	8	27
1091-92S	-40	B	34		0	20	14	1	1	8	5	9	10	1	34
1097-98S	-41	B	29		0	25	4	4		1		4	12	12	29
1099-1100S	-42	B	34	3	0	37		4		1	4	10	7	15	37
1101-02S	-43	W		38	0	38		5		3	4	8	11	12	38
1103-04S	-44	W		23	0	23		5			2	2	8	11	23
1105-06S	-45	B	22	6	0	20	8	5					8	20	28
1111-12S	-46	B	39		0	39		2	1	4	4	13	7	10	39
1113-14S	-47	B	37		0	32	5	2	3	11	11	10	2		37
1115-16S	-48	B	29	8	0	27	10	1	6	8	6	6	9	2	37
1117-18S	-49	B	40		0	40		5		1		7	12	20	40
1119-20S	-50	W		37	0	37		3	1	4	3	2	20	7	37
1125-26S	-51	B	27		0	27		4				1	6	20	27
1127-28S	-52	W		35	0	29	6	3	1	1	3	2	10	18	35
1129-30S	-53	B	45		0	43	2	2		5	3	11	14	12	45
1131-32S	-54	B	36		0	34	2	3					11	25	36
1133-34S	-55	B	27	9	0	36		1	11	8	7	8	2		36
1139-40S	-56	B	20	5	0	22	3	3				4	17	4	25
1141-42S	-57	W		23	0	23		5						23	23
1143-44S	-58	B	7	3	0	10		4						10	10
1145-46S	-59	B	18	7	0	20	5	1	2	5	5	4	7	2	25
1147-48S	-60	W		28	0	26	2	2	2	5	2	15	3	1	28
1153-54S	-61	W		32	0	32		2	1	3	1	7	12	8	32
1155-56S	-62	W		39	0	37	2	4				5	12	22	39
1157-58S	-63	B	23	10	0	6	27	2	13	4	7	6	3		33
1159-60S	-64	B	32	10	0	39	3	2	7	7	3	11	13	1	42
1161-62S	-65	B	24	11	0	27	8	3	5	8	8	5	9		35
1167-68S	-66	W		40	0	40		3	2	9	11	10	7	1	40
1169-70S	-67	W		33	0	33		4		1	2	4	13	13	33
1171-72S	-68	B	23	6	0	29		3	5	2	3	5	6	8	29
1173-74S	-69	W		43	0	37	6	2	1	5	6	15	11	5	43
1175-76S	-70	B	35		0	35		3				6	18	11	35
1181-82S	-71	B	28	10	0	37	1	3	6	5	7	3	10	7	38
1183-84S	-72	B	27		0	5	22	4				7	12	8	27
1185-86S	-73	B	31	5	0	36		3	1	2	4	8	14	7	36
1187-88S	-74	B	36		0	36		4				1	7	28	36
1189-90S	-75	B	24	7	0	31		3				3	15	13	31

TABLE 33.—Relation Between Color of Grain and Awn Development in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

Year	Color of Grain	Numbers or Per Cent	Type of Awns 0	1	2	3	4	5	Total	X^2	P
1923	Black	Numbers	6	37	63	136	105	101	448	12.6505	.0286
	Black	Per Cent	1.34	8.26	14.06	30.36	23.44	22.54			
	White	Numbers	3	14	30	48	27	15	137		
	White	Per Cent	2.19	10.22	21.90	35.04	19.71	10.95			
1924	Black	Numbers	3	21	25	50	111	105	315	4.6457	.4632
	Black	Per Cent	0.95	6.67	7.94	15.87	35.24	33.33			
	White	Numbers	2	9	8	15	39	25	98		
	White	Per cent	2.04	9.18	8.16	15.31	39.80	25.51			
Both Years	Black	Numbers	9	58	88	186	216	206	763	7.1959	.2894
	Black	Per Cent	1.18	7.60	11.53	24.38	28.31	27.00			
	White	Numbers	5	23	38	63	66	40	235		
	White	Per Cent	2.13	9.79	16.17	26.81	28.09	17.02			

TABLE 34.—Relation Between Panicle Type and Awn Development in F_2 Progenies of the Cross Sparrowbill with Victor and Reciprocal.

	Type of Panicle	Numbers or Per Cent	Type of Awns						Total	X^2	P
			0	1	2	3	4	5			
1923	Open	Numbers	8	42	81	173	126	116	546	72.8671	....
	Open	Per Cent	1.47	7.69	14.84	31.68	23.08	21.25			
	Side	Numbers	1	9	12	11	6	0	39		
	Side	Per Cent	2.56	23.07	30.77	28.21	15.38	0			
1924	Open	Numbers	5	28	28	60	140	123	384	17.1183	.0066
	Open	Per Cent	1.30	7.29	7.29	15.63	36.46	32.03			
	Side	Numbers	0	2	5	5	10	7	29		
	Side	Per Cent	0	6.90	17.24	17.24	34.48	24.14			
Both Years	Open	Numbers	13	70	109	233	266	239	930	35.2186	.000,01
	Open	Per Cent	1.40	7.53	11.72	25.05	28.60	25.70			
	Side	Numbers	1	11	17	16	16	7	68		
	Side	Per Cent	1.47	16.18	25.00	23.53	23.53	10.29			

Bulletin 203

August, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Fertilization of Apple Orchards, II

Fig. 4.—St. Marys Experiment Showing Check Plot on Left and Plot Fertilized with Nitrate, Phosphate, and Potash. (See page 28.)

By

M. J. DORSEY and H. E. KNOWLTON

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------President of the University
HENRY G. KNIGHT, Ph. D.--------------Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr.--------------------Agricultural Editor
JOHN C. JOHNSON----------------------------------Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
T. E. Odland, Ph. D. — Associate Agronomist
D. R. Dodd, M. S. — Assistant Agronomist
T. C. McIlvaine, Ph. D.*† — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, B. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
E. C. Stilwell, M. S. — Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
T. J. Cochrane, M. S. — Junior Chemist
Paul Daughenbaugh — Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
G. Malcolm Trout, M. S. — Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
L. E. Dills, B. S.** — Assistant in Entomology

ZOOLOGY

F. E. Chidester, Ph. D. — Zoologist

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul E. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, Jr., M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D. — Home Economist
Nell Nesbitt, A. M. — Home Management Specialist

HORTICULTURE

-------------------- — Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
H. P. Sevy, B. S. Agr. — Assistant in Horticulture
A. L. Tener, B. S. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D. — Associate Soil Technologist

RURAL SOCIOLOGY

T. L. Harris, Ph. D. — Sociologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Fertilization of Apple Orchards, II *

Further refinement in the different operations involved in producing better fruit cheaply will center attention more and more upon the care of the orchard. The great variety of conditions under which apples are grown in West Virginia make it difficult to determine with assurance what are the best cultural practices. An attempt has been made in the experiments reported here to obtain information as to the influence of certain orchard practices upon the tree under different methods of care. These experiments have been in progress for a sufficient length of time to indicate the general bearing of the different variables in the treatment upon both growth and production.

This bulletin in part is a continuation of the experiments first described in Bulletin 174 of this station (Alderman and Crane, 1920). In the St. Marys, Sleepy Creek, and Rome experiments the growth and yield records are given completely for the entire period of investigation. The results of the first seven years of the Cultural Experiment are given here for the first time. It will be seen from the general trend of the first three experiments that considering the results for the entire period certain changes in the recommendations appear justified.

RESULTS OF THE MORE RECENT EXPERIMENTS IN APPLE FERTILIZATION

A number of experiment stations have reported the results of studies on apple fertilization since West Virginia Bulletin 174 was published. Without going into detail it may be stated that the general tendency of the later results is much the same as those reported earlier. Nitrogen has been the only fertilizer to which the apple has, in general, given a profitable response. Anthony and Waring (1922), in Pennsylvania, found results comparable to those of Hedrick (1914), in which sod plots showed a marked response to nitrogenous fertilizers while cultivated plots where cover crops were grown did not. In Maine, Sax (1925) reported similar results. Likewise, in Ohio, Ballou (1920 and 1925) drew similar conclusions except that he found an increase in yield in some cultivated orchards which

*At the time this manuscript was prepared the senior author, Dr. M. J. Dorsey, was head of the Department of Horticulture, which position he resigned September 1, 1925.

was less marked than in sod. In his experiments in the sod plots in one orchard, phosphorus also increased the yield, presumably by increasing the growth of clover that later supplied the nitrogen to the trees. In the New Hampshire tests, (Gourley 1919), increased growth resulted from the use of nitrogen-carrying fertilizers but there was no increase in yield during the first ten years of the experiment, 1908 to 1918, but at the time of this writing, according to Chandler (1925), nitrogen was beginning to show beneficial effects following further depletion of the initial fertility. In Massachusetts, Shaw (1924) found that trees growing in sod and receiving nitrogen produced a better growth than cultivated trees without nitrogen. Cooper (1920), in Arkansas, reported a larger set of fruit following nitrate applications. In New York, (Collison 1920, Collison and Harlan 1923) no fertilizer has produced any beneficial results in any of the cultivated orchards studied. Hedrick and Tukey (1924) said regarding one orchard, "when we come to summarize the effects of the fertilizer treatments in the orchard, we are forced to conclude that they have made absolutely no impression upon the behavior of the trees." The soils in these orchards are deep and fertile. Lyon, Heinicke, and Wilson (1923), in an orchard of young Delicious trees at Ithaca, New York, obtained marked results in growth in sod plots from the use of nitrate of soda.

Turning now to the Pacific Northwest for additional data we find that Morris and Larsen (1921), in tests made in the Wenatchee Valley, found very good results from the use of nitrogen-carrying fertilizers in orchards which had been clean cultivated for several years, but no pronounced results in orchards in which a good cover crop had been grown for more than three years. No evident responses have been observed from applications of either acid phosphate or potash. Lewis, Reimer, and Brown (1920) report similar results in Oregon.

In summarizing briefly the results on apple fertilization in other states, it can be said that apple trees in sod generally need nitrogenous fertilizers for maximum production while apple trees under cultivation may or may not, depending on the fertility of the soil. Acid phosphate seems to be valuable in stimulating cover crop growth only. Applications of potash have shown no favorable response. It will be seen later that the West Virginia experiments, in general, corroborate those summarized above.

THE WEST VIRGINIA EXPERIMENTS

The main features of the four experiments reported in this bulletin are given in the following order: (1) The St. Marys Experiment which is located in the orchard of Mr. L. E. Reynolds, three miles from the city of St. Marys, Pleasants County, on the hills adjacent to the Ohio River Valley; (2) The Sleepy Creek Experiment with Grimes, Ben Davis, and York; (3) The Rome Experiment at Sleepy Creek; and (4) The Cultural Experiment on the Horticultural Farm near Morgantown. The two Sleepy Creek experiments are located in Morgan County in the orchard now owned by the American Fruit Growers, Incorporated. These experiments, therefore, are located in the fruit centers of the state and include different soil types in each instance.

The St. Marys Experiment

This experiment was started in the spring of 1911. The trees were twenty years old, of the Rome variety, and were making only from one to three inches of terminal growth each year. At the time the experiment was started the trees were filled with dead branches and seemed to be upon the verge of starvation. The first season the orchard was thoroughly pruned, sprayed, and cultivated. The soil type is a Dekalb silt loam which is generally recognized as one of the poor soil types of the state. Beginning with plot 2, the soil in this particular location becomes progressively poorer toward Plot 10. This fact should be kept in mind in studying the data from this experiment. When the plots were laid out the orchard had not been cultivated for some time and supported only a meagre growth of grass or weeds. The general condition was such as to furnish an excellent opportunity to study the influence of the different fertilizers when applied to devitalized trees growing in poor soil.

The experiment included ten rows or plots with twelve trees per plot making a total of 120 trees. Each plot received the following applications of fertilizers in pounds per tree: Plot 1 and 6 muriate of potash 2.08 pounds, and acid phosphate 7.8 pounds; plots 2 and 7 nitrate of soda 2.6 pounds, acid phosphate 7.8 pounds, and muriate of potash 2.08 pounds; Plots 3 and 8 nitrate of soda 2.6 pounds, and acid phosphate 7.8 pounds; Plots 4 and 9 nitrate of soda 2.6 pounds, and muriate of potash 2.08 pounds; plots 5 and 10 were checks and

received no fertilizers. The applications were made at this rate until 1915; since then the amount given to each tree has been doubled. In 1911, sulphate of potash was used instead of muriate, and in 1916 and thereafter until 1920, the use of potash was discontinued because of the shortage during the war.

The cultivation which was used at first after the period of neglect was continued until the fall of 1917 when the entire block was seeded to red clover. This crop was plowed under the following spring. In the fall of 1918, the block was again seeded to red clover. Cover crops of cowpeas were grown in 1911, 1912, 1914, and 1917. With the exception of 1911, the crops of cowpeas were light and hence did not furnish a good cover. Following 1918, a volunteer crop cover of natural vegetation, made up of grass and weeds, was allowed to stand. This growth was heaviest in the plots receiving acid phosphate or nitrogen and was cut once or twice each season and left on the ground. No cultivation was practiced after 1918 on account of the severe washing in some parts of the orchard. After this experiment was under way, Plot 1 was discarded since it became evident that it was an outside row and hence was more favorably located than the other plots. This report covers the period from 1911 to 1924, or fourteen seasons, but only ten crops.

The Sleepy Creek Experiment

This experiment was started in the spring of 1913, in the orchard of S. H. Fulton, now owned by the American Fruit Growers, Incorporated. The soil is a shallow Holston loam with a shale subsoil. The humus content was low and during dry periods in summer the trees often showed a moisture deficiency. The part of the orchard in which this experiment was located was planted in blocks of five rows each of Grimes, Ben Davis, and York. The ten plots of the experiment run crosswise of these varieties, making five trees of each variety in each treatment. The plot arrangement was similar to the Rome experiment but two additional check rows were added. The different combinations of fertilizers and the rate of application from 1913 to 1924, inclusive, are given in Table 1.

TABLE 1.—Fertilizer Applications and Plot Treatments in the Sleepy Creek Experiment with Grimes, Ben Davis, and York.

Plot	Treatment	Fertilizer Application in Pounds per Tree**				
		1913-1919	1920	1921-1922	1923	1924
1	Check	....	....	....	....	....
2	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Acid phosphate	2.5	2.5	8.0	8.0	10.0
3	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Muriate of potash*	1.0	1.0	1.5	1.5	2.0
4	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Acid phosphate	2.5	2.5	8.0	8.0	10.0
	Muriate of potash	1.0	1.0	1.5	1.5	2.0
5	Acid phosphate	2.5	2.5	8.0	8.0	10.0
	Muriate of potash	1.0	1.0	1.5	1.5	2.0
6	Check	....	....	....	....	....
7	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
8	Acid phosphate	2.5	2.5	8.0	8.0	10.0
9	Muriate of potash	1.0	1.0	1.5	1.5	2.0
10	Check	--	--	--	--	---

*No potash was added for the three year period beginning with 1916 on account of the shortage during the war.
**Applied at time of blooming.

It will be seen that the amount of the fertilizers added was increased after 1920. This seemed advisable on account of the relatively light applications made during the first seven years of the experiment and because of the increased size of the trees which was accompanied by a reduction in the terminal growth. While the amount of nitrate of soda applied (1.5 pounds per tree), during the period of this experiment reported on in Bulletin 174, 1913 to 1919 inclusive, was small for trees nine to sixteen years old, it will be seen by referring to Table 5 that the terminal growth during these years was adequate.

The orchard in which this experiment was located was cultivated each year. In late July or early August a cover crop was sown annually; some seasons this was good and others light. From 1919 to 1922, inclusive, red clover was sown. Since then rye has been used. The planting distance was 25 feet each way. It will be seen

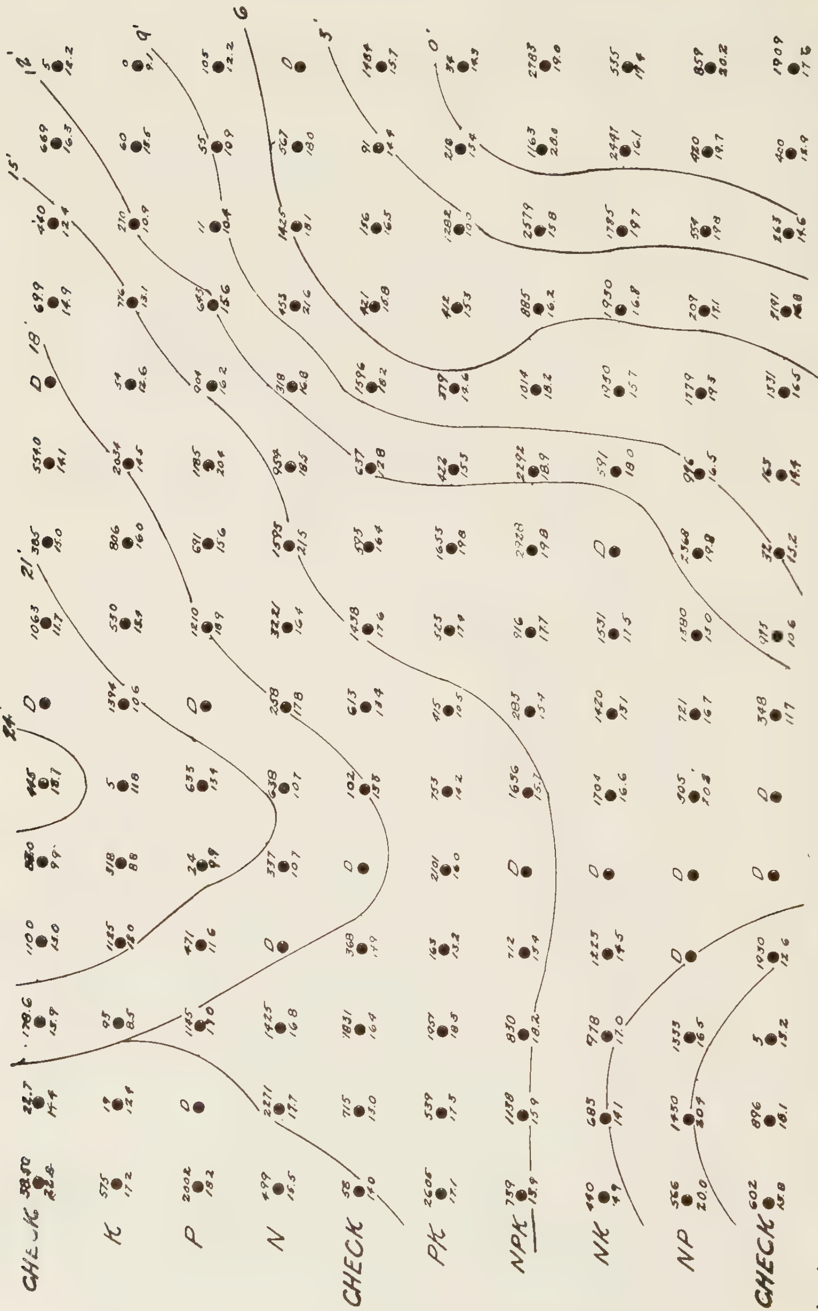


Fig. 1.—Contour Map of Sleepy Creek Experiment with Individual Tree Yields and Trunk Circumferences, 1913-24.

from Table 5 that the trees were making a satisfactory growth at the beginning of the experiment. From the first this orchard was plowed each year in early spring with frequent cultivation later with disc or harrow. In later years in certain parts of the orchard soil erosion was serious and more recent plowings, especially the last one, resulted in rather serious root cutting on trees in the shallower soils (Dorsey and Knowlton 1924). The cultivation was in one direction, following the contours, until in the last two years when cross cultivation was also practiced. A contour map of this experiment is shown in Figure 1.

These trees were pruned to the open head system with five to seven scaffold limbs. In 1915, the terminal twigs were headed back which resulted in thickening the top. Since then some thinning out of the top has been necessary. This kind of pruning gave a type of tree which was sufficiently open but which was inclined to have long branches with laterals too far away from the head.

The Rome Experiment

This experiment was started at Sleepy Creek in the orchard of S. H. Fulton in 1911. On account of the fact that the experiment at St. Marys was also with Rome, but with older trees, this experiment was referred to in Bulletin 174 as the "Young Rome Experiment." Since this term might be misleading now, it will be referred to in this bulletin as the Rome Experiment. The trees were only one year old at the time the first fertilizer applications were made. The planting distance was twenty-four feet on the quincunx plan. The soil in this plot is classified as a Holston silt loam, and was fairly high in fertility, as shown by the following analysis taken from Bulletin 168. In parts of 2,000,000 pounds of soil at plow depth, nitrogen ran 2,110 pounds, phosphorus 608, and potassium 22,840. The initial fertility may be partly accounted for by the fact that this orchard was planted in "new ground."

The amounts of each fertilizer were increased in 1921. As in the other experiments no potash was applied for the three-year period beginning with 1916.

Cultivation has been practiced each year since the orchard was started. The intercrop the first two years was corn. Since then clover, or that failing, a growth of weeds was allowed to cover the ground in late summer and fall and plowed under in the spring.

TABLE 2.—Plot Arrangement, Treatment, and Rate of Application of Fertilizers in the Rome Experiment at Sleepy Creek.

Plot	Treatment	Fertilizer Applications in Pounds per Tree*				
		1911-13	1914-15	1916-19	1920	1921-24
1	Nitrate of soda	.75	1.00	1.5	1.5	4.0
	Acid phosphate	1.25	1.75	1.5	1.5	4.0
2	Nitrate of soda	.75	1.00	2.5	2.5	8.0
	Muriate of potash	.50	.75	-------	1.0	1.5
3	Nitrate of soda	.75	1.00	1.5	1.5	4.0
	Acid phosphate	1.25	1.75	2.5	2.5	8.0
	Muriate of potash	.50	.75	-------	1.0	1.5
4	Acid phosphate	1.25	1.75	2.5	2.5	8.0
	Muriate of potash	.50	.75	-------	1.0	1.5
5	Check	-------	-------	-------	-------	-------
6	Nitrate of soda	.75	1.00	1.5	1.5	4.0
7	Acid phosphate	1.25	1.75	2.5	2.5	8.0
8	Muriate of potash	.50	.75	----	1.0	1.5

*Applied at time of blooming.

During the years 1919 to 1923, red clover only was sown as a cover. In 1924, the plots were seeded to crimson clover. The cover crop growth was not sufficiently heavy, in general, to account for the uniformity in tree growth and the trees to date have not been sufficiently productive to draw heavily upon the relatively high initial fertility. The close planting even with the size of tree now reached has no doubt made it possible for cross feeding to take place between the plots. If this has taken place it has made no difference between the general appearance of these trees and the others in the orchard immediately adjacent. Because of this possibility however, and because there is but one check plot, the experiment has been discontinued.

In the earlier years of this experiment some heading back was practiced. This resulted in a relatively thick growth in the top. Since then the pruning has been light and has consisted, for the most part, of thinning out.

Cultural Experiment on the Horticultural Farm

The cultural experiment at Morgantown was started in the spring of 1917 with the object of making a study of some of the different systems of orchard management in use in West Virginia. The project was planned to study the variations encountered in the two general methods of orchard culture, namely, permanent sod and cultivation. Mine drops occurred in Plots 2, 3, and 4 in 1923, and a fire was accidentally set during the spring of 1923 in Plots 10 and 11. These two accidents made it necessary to discontinue this experiment according to the original plan.

The general plan of this experiment can be seen in Table 3, where the treatment of each plot is given. In plots 1 to 4 annual cultivation with a cover crop, either leguminous or non-leguminous, was practiced each year. In these plots manure, nitrate of soda, and acid phosphate were entered as variables. Plots 5 and 6 were intermediate between cultivation and a permanent sod. In the six plots remaining, the treatments called for a permanent sod of either grass or alfalfa, in which fertilizers, manure, and mulch were entered as variables. In this series, the trees were subjected to treatments in which the moisture and nitrogen relations were varied in several ways.

The trees in this experiment were trained, for the most part, to four scaffold limbs with a central leader bearing three or four laterals. The head was formed approximately twenty inches from the ground with the second story from thirty-six to forty-eight inches above the main scaffold branches. An attempt was made to prune all plots uniformly each season, but it was necessary to cut somewhat heavier on the cultivated plots because of the greater growth of both laterals and water sprouts. The kind of pruning can best be described as a light to moderate dormant pruning. The trees were planted thirty feet apart each way on the diagonal and when set were one year old and were carefully selected for uniformity.

The cultural program was for the most part, carried out as scheduled. Some variations, however, were necessary. In Plot 5, where it was planned to have sod and cultivation alternate in the rows, it has been difficult to get an even stand of grass during dry seasons. On account of this the treatments were not alternated annually as planned, but were alternated biennially. This resulted in a rather uneven growth of the cultivated and the sod sides of the

TABLE 3.—Plan of the Cultural Experiment with Delicious and Wealthy on the Agricultural Experiment Station Farm at Morgantown.*

Plot	Treatment 1917-1923	Row	Remarks
1	Cultivation with leguminous cover crop	1 2 3	Seeded to crimson clover and vetch. Cover crop turned under in late May or early June, with cultivation during the summer. Seeding rate 15 pounds per acre.
2	Cultivation with non-leguminous cover crop	4 5	Rye used each year and turned under in late May or early June. Seeding rate 1½ bushels per acre.
3	Cultivation, manure, and non-leguminous cover crop	6 7	Rye used as cover crop at rate of 1½ bushels per acre with manure at the rate of 12 tons per acre applied in May or June.
4	Cultivation, nitrate of soda, acid phosphate, and non-leguminous cover crop	8 9	Rye was sown as the cover crop. Nitrate of soda was applied at the rate of 150 pounds per acre and acid phosphate at the rate of 450 pounds per acre in late May or early June.
5	Sod with alternate rows in cultivation	10 11	The sod strip seeded with timothy, orchard grass, tall oat grass, and red top. The alternation of sod strip with cultivation has been irregular.
6	Sod with tree rows only cultivated	12 13	Sod formed with same combination as in Plots 4 and 5. The row strip was cultivated throughout the summer.
7	Alfalfa sod	14 15	The alfalfa was seeded at the rate of 20 pounds per acre and has been cut about three times each season and left on the ground.
8	Sod, nitrate of soda, and acid phosphate	16 17	Seeded to a combination of timothy, tall oat grass, orchard grass, and red top. Grass cut twice each season and left as it fell. Nitrate of soda applied at the rate of 150 pounds per acre and acid phosphate at 450 pounds per acre.
9	Sod and manure	18 19	Sod formed by the same seeding as in Plot 8. Manure applied in early spring at rate of 12 tons per acre.
10	Sod	20 21	Sod formed as in Plot 8. No grass removed after the cuttings.
11	Sod and additional straw mulch	22 23	Sod formed as in other plots. The mulch was formed with a wheat straw covering 4 to 6 inches deep, extending to the tips of the branches.
12	Alfalfa sod	24 25	Seeded as in Plot 7. After cutting as in the others the growth was left as it fell.

*Delicious and Wealthy alternate in each row.

trees. An error was made in the application of manure in 1923 to plot 3, when row 5 of Plot 2 and row 6 of Plot 3 received the application instead of rows 6 and 7 of Plot 3. The grass was cut three times each season in the sod plots and left on the ground as it fell. The strip cultivated in the tree row in Plot 6 was twelve feet wide. In Plot 11, the mulch of wheat straw was four to six inches thick and was about ten feet in diameter. The alfalfa in Plots 7 and 12 gradually became thinner after seeding, but was not renewed during the period of this report. The applications of nitrate of soda, acid phosphate, and manure were made evenly over the entire area of the plots.

THE EFFECT OF FERTILIZERS AND CULTURE ON GROWTH

The response of the trees in these experiments to the different treatments was determined each season by measuring the growth of the terminal twigs and the enlargement of the trunk. In addition to these two measurements, the size of the trees in the different plots of three of the experiments was determined at the end of the period reported upon. These three indices of tree response were selected as a means of comparing the growth under a given treatment with that of the checks or of another treatment. The data under these three headings are presented in the foregoing order.

Terminal Twig Growth

In taking the terminal twig measurments presented in the following tables, ten terminal twigs were selected at random from the limbs around the sides of each tree in a plot. In making the measurements in the orchard a fifty foot cloth tape was found to be most convenient because at the tenth measurement the total could be read directly and entered into the records. The average length of the terminal growth was computed for each tree. From these averages, the average twig length for the plot was then obtained.

The St. Marys Experiment.—Twig growth measurements were not taken on all of the trees of the St. Marys experiment until 1918, although data were presented in Bulletin 174 on the growth rate of twigs in Plots 2 and 5, for the years 1911 to 1919 inclusive. The earlier results showed a marked increase in growth in check Plot 5, as a result of the rejuvenation treatment, but there was a still greater growth, averaging three inches more, in Plot 2 which received a complete fertilizer.

TABLE 4.—Effect of Fertilization on Terminal Twig Growth in the St. Marys Experiment.

Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths Per Tree							Av'ge.
		1918	1919	1920	1921	1922	1923	1924	
2	N P K	10.20	7.16	8.45	3.33	4.73	4.24	3.23	5.90
3	N P	9.70	7.36	7.71	2.86	3.88	3.50	2.33	5.33
4	N K	9.60	5.68	6.60	2.94	3.94	3.72	2.87	5.05
5	Check	6.20	3.34	4.22	1.51	1.71	1.64	0.95	2.79
6	P K	7.30	4.60	5.35	1.98	1.90	1.85	0.91	3.41
7	N P K	9.80	7.06	8.57	2.67	4.09	3.23	1.87	5.33
8	N P	10.20	6.99	8.60	2.83	4.60	2.95	1.73	5.41
9	N K	9.30	6.66	6.30	2.85	3.30	3.13	1.72	4.75
10	Check	6.20	3.59	3.33	1.23	1.23	0.99	0.65	2.46

The complete record of terminal twig growth in the St. Marys experiment, from 1918 to 1924, is given in Table 4. The results show substantial increases for all plots receiving nitrate of soda (see Figure 2). Plot 6, to which acid phosphate and muriate of potash were applied, made terminal growths slightly better than the adjacent check. The odds, however, calculated by Student's method (Student 1918, Love 1924), were 87:1, which indicated a significant difference.* The best plot in the experiment was number 2, which received a complete fertilizer. It was on lower ground and undoubtedly had more fertile soil. When the terminal growth made in the last four years of the experiment is compared with that of the earlier years after the treatments were begun, it will be seen that there was a marked reduction in twig growth. In the nitrated plots this reduction in twig growth accompanied increased production, lighter pruning, and also a larger size of tree. In the plots not receiving nitrogen the decreasing growth undoubtedly indicates progressive stages in soil exhaustion.

The Sleepy Creek Experiment.—In Table 5, the average terminal shoot growth is given for 1913 to 1924, the period when these trees were from nine to twenty years of age. The measurements were not made in 1915 on account of the heavy pruning given the trees that year. The average growth under each treatment for the entire period was not computed, as the rather wide differences in annual growth make this figure of little value.

*Odds of 87:1 mean that the odds are 87 to 1 against the possibility of a difference as great as this occurring due to chance alone. These odds must be at least 30:1 to be significant.

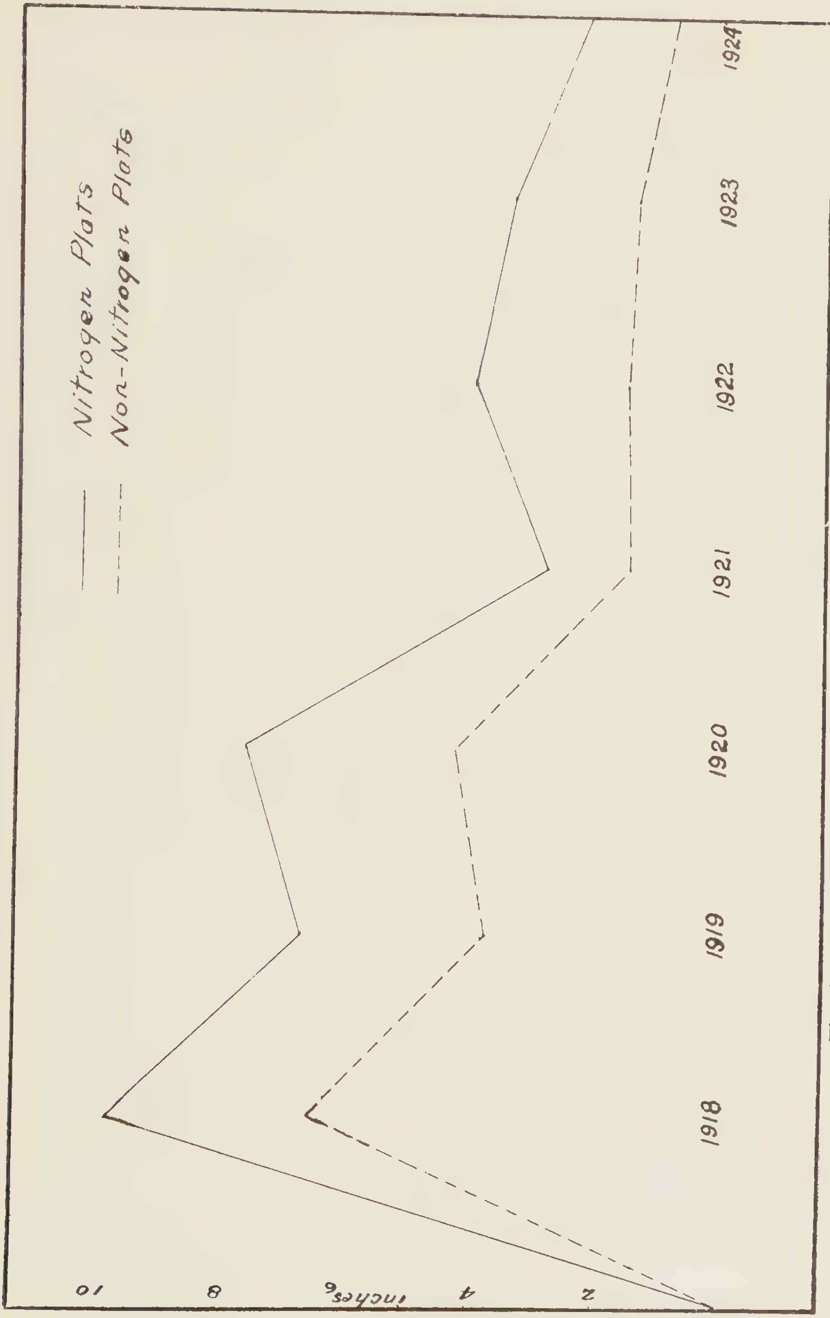


Fig. 2.—Average Annual Terminal Growth, St. Marys Experiment.

TABLE 5.—Effect of Fertilization on Terminal Twig Growth in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths or Shoots per Tree											Odds in Favor of the Treatment	Odds in Favor of the Check
			1913	1914	1916	1917	1918	1919	1920	1921	1922	1923	1924		
Grimes	1	Check	13.80	10.60	18.20	9.00	6.37	6.22	10.40	7.47	6.96	5.17	4.25		
	2	N P	17.23	16.73	22.26	10.70	8.83	7.46	9.70	9.53	11.16	5.60	5.27	1666:1	
	3	N K	9.07	9.60	18.25	9.75	8.30	8.87	10.35	8.85	12.30	5.47	2.82	25:1	
	4	N P K	11.57	8.61	23.20	12.30	9.75	9.72	10.97	8.60	8.40	4.80	5.26	19:1	
	5	P K	14.86	13.31	21.52	10.06	7.06	7.14	10.14	7.72	9.00	4.92	2.48	10:1	
	6	Check	15.37	11.37	21.85	9.70	7.65	6.07	8.18	8.37	6.80	4.74	3.28		
	7	N	13.62	11.30	21.30	11.27	9.85	8.92	9.65	7.50	7.38	5.24	3.70	8:1	
	8	P	10.50	10.26	19.24	9.70	6.28	6.16	10.42	8.41	6.72	3.54	2.44		10:1
	9	K	9.74	10.04	18.64	8.88	5.62	4.62	10.93	8.56	6.06	3.36	2.32		30:1
	10	Check	7.89	10.38	20.44	10.92	6.00	6.82	10.12	8.32	7.56	2.16	2.74		
Ben Davis	1	Check	11.20	9.15	15.64	10.70	7.60	6.00	6.02	6.52	9.45	5.44	5.10		
	2	N P	12.04	10.38	20.56	11.42	10.00	7.10	9.44	8.40	8.82	4.80	5.70	129:1	
	3	N K	10.10	9.68	18.90	11.50	10.40	9.70	9.42	7.25	13.32	4.80	5.22	75:1	
	4	N P K	11.60	10.55	19.36	10.82	10.26	9.14	8.88	7.12	10.98	4.32	6.56	446:1	
	5	P K	11.12	11.07	17.76	10.42	11.64	8.18	7.62	5.58	6.36	4.20	3.48	3.5:1	
	6	Check	10.50	11.76	19.68	10.82	8.02	5.70	6.06	4.28	6.18	4.52	3.94		
	7	N	11.46	12.45	22.68	11.60	10.58	8.58	8.82	6.86	9.12	4.20	4.22	2499:1	
	8	P	11.18	11.92	21.16	11.96	8.58	6.05	5.05	3.58	7.20	4.43	3.85	349:1	
	9	K	8.25	10.86	19.20	10.16	7.32	4.44	4.70	4.00	5.58	3.30	3.27	even	
	10	Check	7.22	10.35	16.84	10.68	7.28	5.80	4.17	2.67	7.50	4.27	2.65		
York	1	Check	17.78	14.82	20.64	10.36	6.16	5.50	4.70	3.78	4.74	4.20	3.74		
	2	N P	15.06	13.02	22.84	12.14	7.44	7.42	5.52	8.68	7.00	4.14	4.00	23:1	
	3	N K	14.28	11.76	21.48	11.72	8.46	9.84	4.86	6.70	7.08	3.48	5.12	22:1	
	4	N P K	11.56	11.34	21.28	11.76	7.60	9.00	5.38	8.12	6.84	4.20	4.77	13:1	
	5	P K	12.08	14.10	19.32	9.66	6.40	5.04	3.08	2.90	4.26	3.24	3.32	even	
	6	Check	13.14	15.73	19.16	9.96	5.10	4.16	3.04	2.20	3.66	2.34	3.28		
	7	N	10.85	11.70	22.50	11.30	6.25	7.70	7.27	6.81	6.78	3.53	4.50	52:1	
	8	P	8.82	10.52	17.04	9.66	5.00	4.28	4.80	4.72	6.30	2.94	3.20	even	
	9	K	8.34	6.61	16.88	9.48	4.60	4.54	3.74	3.32	3.36	1.98	1.92		5:1
	10	Check	9.17	11.11	18.10	9.57	4.90	5.25	3.76	3.10	4.98	3.76	2.90		

The responses to the different treatments were studied by Student's method. In using this method a "theoretical or calculated" check was made the basis of comparison, that is, each check was computed from the values of the two nearest checks, the value being proportional to the relative distances from the plot to be compared. When comparisons are made in this way and the odds computed, it will be seen that the only consistent responses to fertilizers have been made by Ben Davis. In this block all applications containing nitrate of soda showed significant increases in twig growth. In the Grimes block the plot to which nitrate and phosphate have been applied is the only one that showed a significant increase. In the York block only the nitrate plot showed a significant response. It should be noted, however, that all plots receiving nitrate showed odds in favor of the treatment. This is not true for the plots receiving potassium or phosphorus.

The Rome Experiment.—The average terminal twig growths in the thirteen-year-old Rome block at Sleepy Creek are shown in Table 6. Unfortunately this experiment has but one check plot. Because of possible differences in soil it was thought best to make comparisons between contiguous plots only.

When these comparisons were made by Student's method, no treatment in this experiment showed a significant increase over the adjacent one. It will be remembered, however, that the soil in this orchard was fairly fertile and that the orchard was cultivated. When it is considered that twig growth on the checks averaged more than twenty-four inches at the beginning of the experiment in 1914, and more than nine inches when the trees were twelve years old in 1923, it is not surprising that increased growth did not result from the fertilizer applications.

The Cultural Experiment.—In this experiment the influence of a number of treatments on terminal twig growth can be studied in Table 7. Sod Plot 10 was used as a basis of comparison and the odds were calculated according to Student's method. Reference is made to both varieties in the discussion of results at the end of this bulletin.

All other treatments gave significantly better growth than did sod. A legume cover crop in Plot 1 with Wealthy gave more terminal growth than the non-legume cover crop in Plot 2 (63:1). With Delicious the odds are hardly significant (25:1). These results are

TABLE 6.—Effect of Fertilization on Terminal Twig Growth in the Rome Experiment.

Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths or Shoots per Tree										
		1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
1	N P	22.47	38.80	35.87	11.46	12.98	13.38	9.97	11.61	9.34	8.96	5.40
2	N K	23.14	32.40	34.82	14.67	17.44	14.49	8.51	11.97	9.66	9.29	6.56
3	N P K	28.84	37.80	36.00	15.20	15.93	13.63	8.45	12.85	10.57	9.53	7.38
4	P K	23.31	30.83	28.94	16.27	15.54	13.10	10.30	13.75	10.83	9.90	6.28
5	Check	24.76	31.04	27.78	15.06	13.82	12.97	9.35	11.68	9.30	9.26	6.84
6	N	23.46	33.58	35.36	16.15	17.54	13.67	8.32	11.58	9.63	9.81	7.17
7	P	22.41	34.26	29.44	13.84	14.20	12.59	8.78	12.29	9.36	9.09	6.39
8	K	22.00	36.20	31.29	16.39	13.77	12.01	8.08	11.37	9.72	9.39	6.41

surprising because the cover crop growth in Plot 1 was not heavy and do not agree with those of Oskamp (1920) in Indiana, where rye proved to be a much better cover crop as measured by the organic matter and nitrogen returned to the soil and by the tree growth. With Delicious in this experiment manure did not give a significant increase in growth (14:1) in Plot 3, when comparison is made with Plot 2, to which manure was not applied, but which received the same care otherwise. With Wealthy, however, there was a significant increase (75:1) from the use of stable manure in Plot 3.

In comparing Plots 2 and 4, Delicious showed a significant difference (36:1) in favor of the nitrate and acid phosphate applications as did also Wealthy (30:1). At the time of writing this manuscript (June 1925) very slight, if any, differences could be noticed in the four cultivated plots of this experiment. The trees in Plots 3 and 4 may have had slightly darker green foliage.

Cultivation along with nitrate and acid phosphate in Plot 4 gave no better growth than when these same fertilizers were applied to sod in Plot 8, the odds being 2:1 with both Delicious and Wealthy. In this experiment where manure was applied to a cultivated plot it did not give significantly better growth than where applied to sod with either Delicious or Wealthy. The soil, however, is slightly better in all the sod plots. These results indicate that vigorous tree growth can be secured and maintained at least up to bearing age in sod orchards by applying nitrate of soda in sufficient quantities.

When applications of nitrate of soda and acid phosphate to Plot 8 in sod are compared with manure applications in Plot 9, there seems to be a significant difference in favor of the former with Delicious, (42:1), but not with Wealthy, (1:1). Sod with strip cultivation was better than alternate row cultivation with both Delicious (34:1) and Wealthy (33:1). At the time of this writing the trees in the strip-cultivated plot were much more vigorous and have darker green foliage than the trees in the plot given alternate row cultivation.

The alfalfa sod plot showed a significant increase in twig growth over the grass sod even though the growth of alfalfa was sparse. On account of the poor stand of alfalfa, however, these two plots cannot be considered as having given this crop a fair test in this location.

TABLE 7.—Effect of Treatments on Terminal Twig Growth in the Cultural Experiment.

Plot	Treatment	Average Increase in Inches Based on Ten Growths per Tree												Average		Odds in Favor of the Treatment	
		1918		1919		1920		1921		1922		1923					
		Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy
1	Cultivation and legume cover crop	17	14	19	19	19	22	17	19	17	16	17	18	17.7	18.0	410:1	1666:1
2	Cultivation and non-legume cover crop	16	9	17	18	18	19	16	18	16	15	15	17	16.3	16.0	142:1	454:1
3	Cultivation, manure, and non-legume cover crop	19	11	19	19	21	24	17	20	15	15	17	20	18.0	18.2	179:1	665:1
4	Cultivation, nitrate, acid phosphate, and non-legume cover crop	17	10	18	17	20	22	18	20	16	16	18	20	17.8	17.5	794:1	1110:1
5	Sod and alternate row cultvation	12	9	15	20	15	14	15	16	16	15	14	16	14.5	15.0	65:1	76:1
6	Sod and strip cultivation	21	14	18	19	17	17	16	17	16	16	18	19	17.7	17.0	124:1	4999:1
7	Alfalfa sod	19	12	14	13	16	17	15	15	14	16	17	17	15.8	15.0	58:1	999:1
8	Sod, nitrate ,and acid phosphate	11	11	17	21	17	16	19	19	17	17	21	24	17.0	18.0	1428:1	1999:1
9	Sod and manure	9	11	14	17	15	21	18	19	17	18	21	24	15.7	18.3	369:1	4999:1
10	Sod	8	7	9	11	13	12	12	12	13	11	15	15	11.7	11.3		
11	Sod and additional straw mulch	14	11	15	19	17	16	16	17	14		15		15.2	15.8	115:1	2499:1
12	Alfalfa sod	18	11	14	16	17	20	17	11	14	12	14	13	15.7	13.8	40:1	11:1

Trunk Circumference

Measurements of the increase in the circumference of the trunk were taken each year on all the trees. The measurements were made with a steel tape, usually in late fall after growth had stopped for the season. In order to make the measurements as consistent as possible from year to year a white band at the point of measurement was painted on the trunk at a point about half way up to the lower limbs. In the older trees care was taken to remove the larger flakes of rough bark before making the measurement. The data for trunk circumference in the different experiments are presented in the same order as that for twig growth.

The St. Marys Experiment.—In Table 8 the records of the annual increase in trunk circumference in Rome are given for the period 1916 to 1924 inclusive. It may be seen from either the totals or the annual measurements that there were consistent differences between the plots which received nitrate of soda and those which did not.

TABLE 8.—Effect of Fertilization on Trunk Circumference in the St. Marys Experiment

Plot	Treatment	Average Annual Increase in Trunk Circumference in Inches						Total Increase
		1918*	1919	1921**	1922	1923	1924	
2	N P K	2.32	.79	2.22	1.39	1.22	.65	8.59
3	N P	2.52	.99	1.42	1.28	.88	.60	7.69
4	N K	1.99	.75	1.34	1.40	.66	.23	6.37
5	Check	1.40	.66	.29	.51	.94	.25	4.05
6	P K	1.79	.27	.85	.44	.67	.43	4.45
7	N P K	2.43	.89	1.70	.91	.37	.90	7.20
8	N P	2.10	1.02	1.75	1.06	.53	.61	7.07
9	N K	2.25	.36	2.47	.94	.75	.58	7.35
10	Check	1.45	.46	.41	.72	.25	.16	3.45

*Increase for period of 1916-18. **Increase for period of 1920-21.

All treatments showed significant increases over the checks except Plot 6, to which acid phosphate and muriate of potash were applied. The odds in this instance were only 2:1, which is not significant. The results from the fertilizer applications in this experiment as measured by the increase in trunk circumference correspond in general with the differences shown by terminal twig growth. The differences between the nitrogen plots were probably due to soil variations.

As pointed out in Bulletin 174, no records are available regarding the size of these trees at the beginning of the experiment in 1911. It should be kept in mind, however, that this part of the orchard was chosen for the experiment because of its uniformity. It seems fair to assume, therefore, that the differences existing between the plots at the time of this writing were due to the treatments and that they were cumulative from 1911 to 1916, before the measurements were taken, and also since that time.

The Sleepy Creek Experiment.—The annual increase in trunk circumference was taken each year in this experiment from 1913 to 1924 inclusive. The data are summarized in Table 9. It will be seen that there are a few instances in this table where no increase in growth is shown. This is due to errors in measurement which result from irregularities in the bark or slight variations in placing or reading the tape; that this is the probable explanation may be seen by comparing the figures on either side of these errors. Such discrepancies, however, should not affect the totals appreciably, but they do influence the odds in the comparisons by Student's method.

A "theoretical or calculated" check was used as the basis for comparison in the trunk measurements as in the twig growths. The increases in the different plots were not consistent. None of the treatments in the Grimes block were significant when measured by Student's method. In the Ben Davis section of the experiment nitrate of soda showed a significant increase in Plots 2 and 7. In Plot 5, which received acid phosphate and muriate of potash, the increased growth was significant when compared with the checks as was true in the plots receiving nitrate of soda. This single instance, however, cannot be considered suggestive in view of the results of other experiments. A single plot of York receiving nitrogen (Number 2) showed a significant increase in trunk circumference. The data on the trunk measurements in this experiment agree in general with those on the twig measurements. Emphasis will be placed, later on, in this discussion, upon the probable reason for the general trend of the results in this experiment.

The Rome Experiment.—Emphasis has already been given to the relatively high initial fertility of the soil in this experiment and also to the fact that the trees did not apparently draw heavily upon the available food supply. This general condition was shown in the data on twig growth in Table 6.

TABLE 9.—Effect of Fertilization on Trunk Circumference in the Sleepy Creek Experiment.

	Plot	Treatment	Average Annual Increase in Trunk Circumference in Inches 1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Total Increase	Odds in Favor of Treatment	Odds in Favor of Check
Grimes	1	Check	.89	1.46	2.88	.87	1.69	.93	.84	1.53	1.37	.15	.88	1.24	15.07		
	2	N P	1.18	2.50	2.67	1.20	2.05	2.33	1.00	.58	1.85	.00	2.10	.75	18.51	10:1	
	3	N K	1.15	1.35	2.56	.78	1.47	1.50	1.09	.**	1.63	1.62	.56	.78	15.15	even	
	4	N P K	1.63	1.13	2.72	.93	1.47	1.69	1.37	.81	1.38	1.32	.43	.78	15.66	7:1	
	5	P K	2.01	1.38	3.35	.70	1.45	1.65	1.07	1.48	1.20	.90	.65	.47	16.31	4:1	
	6	Check	1.16	1.47	2.40	1.29	1.46	1.38	1.03	.91	1.44	.00	1.37	.56	14.47		
	7	N	1.71	1.10	1.75	.90	1.56	1.31	1.32	3.33	.00	.00	1.36	.03	15.37	even	
	8	P	1.26	1.08	2.82	.88	2.10	.30	.85	2.50	.00	.90	.60	.15	13.44	even	
	9	K	.49	1.20	2.40	.97	1.18	1.10	.85	.00	2.35	.85	.45	.35	12.19		19:1
	10	Check	1.64	1.12	2.58	1.25	1.25	1.15	.97	.00	2.58	.95	.67	.30	14.46		
Ben Davis	1	Check	.29	1.10	2.70	.57	.58	2.05	1.32	.18	.60	.87	.54	.75	11.55		
	2	N P	1.00	.96	1.34	3.12	1.13	2.25	1.62	.28	1.65	1.65	.75	.65	16.40	85:1	
	3	N K	.90	.96	3.13	1.06	1.56	1.75	2.17	1.15	.50	2.00	.13	.93	16.24	17:1	
	4	N P K	1.83	1.13	2.62	1.00	1.53	1.45	1.95	.70	1.60	1.30	1.05	.57	16.73	30:1	
	5	P K	.99	1.55	3.00	1.37	1.43	1.55	1.82	.78	.70	1.30	.30	.57	15.36	4.5:1	
	6	Check	1.67	1.27	3.45	1.20	1.08	1.75	1.12	.13	1.10	.80	.60	.37	14.54		
	7	N	2.42	1.40	2.95	1.33	1.95	1.70	1.75	.60	1.70	1.15	.62	.78	18.35	350:1	
	8	P	2.16	1.38	3.44	.93	1.73	1.15	1.60	.25	.81	1.19	.75	.43	15.82	28:1	
	9	K	1.40	.98	2.87	1.23	1.35	1.50	.92	.73	.60	.60	.65	.65	13.18	2:1	
	10	Check	1.50	1.13	2.56	.88	1.05	1.20	1.06	.00	.00	1.56	.62	.53	12.09		
York	1	Check	1.82	1.58	2.95	1.29	1.95	1.85	.65	.75	.60	1.05	1.00	.62	15.62		
	2	N P	2.16	1.45	3.00	1.42	2.13	2.15	1.27	1.53	.95	1.55	.85	1.30	19.76	308:1	
	3	N K	1.40	1.28	2.92	1.13	2.20	2.30	1.10	1.40	.65	1.50	.60	.62	17.10	3:1	
	4	N P K	1.54	1.32	2.88	.95	1.50	2.90	1.15	1.50	.75	1.50	.65	.92	17.56	3:1	
	5	P K	1.70	1.57	2.05	1.85	1.48	1.40	.77	1.13	.00	.55	.55	.30	13.35		26:1
	6	Check	2.15	1.95	3.20	1.28	1.95	1.60	.95	.80	.00	.80	.60	.57	15.85		
	7	N	1.70	1.36	2.96	1.09	2.19	.68	1.82	.00	.20	1.35	3.14	.83	15.85	3:1	
	8	P	1.72	.93	2.95	.82	1.13	1.35	1.12	.23	.85	1.00	.35	.55	13.00	even	
	9	K	1.66	.98	2.60	.77	1.18	1.10	.85	.45	.45	.50	.45	.25	11.24		26:1
	10	Check	1.58	1.28	2.22	1.16	1.56	1.19	1.09	.00	.00	.52	1.79	.41	12.80		

TABLE 10.—Effect of Fertilization on Trunk Circumference in the Rome Experiment.

Plot	Treatment	Average Annual Increase in Trunk Circumference in Inches											Total Increase
		1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	
1	N P	1.82	1.95	1.28	2.38	2.33	.99	1.85	1.39	2.38	1.60	.96	18.93
2	N K	1.67	1.57	.92	1.43	2.40	1.81	1.19	2.08	2.10	1.38	1.31	17.86
3	N P K	1.55	2.12	1.09	2.14	2.83	1.97	1.15	2.46	1.59	2.42	.59	19.91
4	P K	1.53	1.59	.72	1.48	2.11	2.32	2.31	2.16	2.39	2.03	1.00	19.64
5	Check	1.74	1.54	.75	1.33	2.00	1.56	1.14	1.77	1.55	3.18	.50	17.06
6	N	1.69	1.65	.80	.57	2.98	1.67	1.08	1.79	2.29	2.65	.32	17.49
7	P	1.77	1.81	.83	1.72	2.00	1.61	1.99	1.87	2.16	1.80	.77	18.33
8	K	1.50	1.90	.67	1.40	1.88	1.57	1.58	1.71	2.09	1.68	1.05	17.03

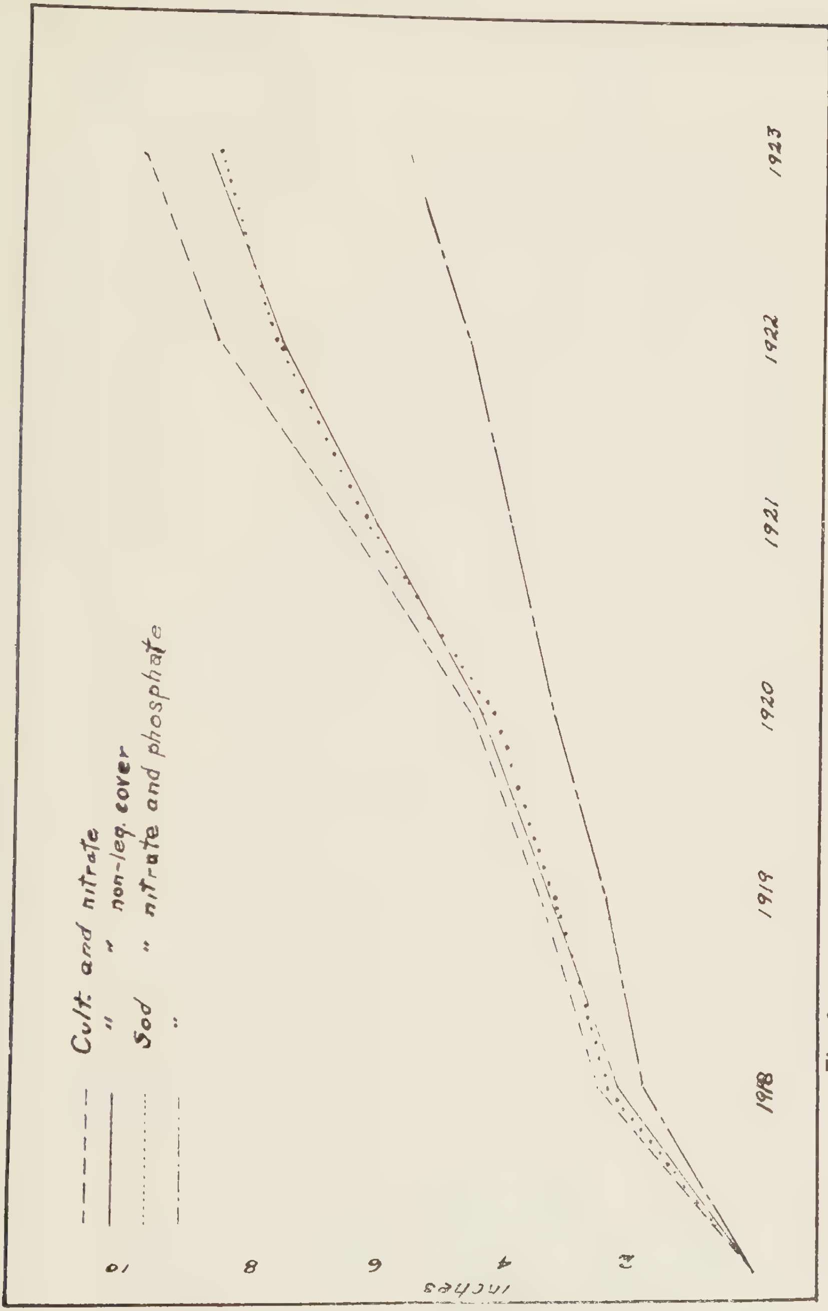


Fig. 3.—Average Trunk Circumference in Cultural Experiment, 1918-1923.

It may be seen from Table 10 that the general trend of the data on trunk circumference follows that on twig measurements in that no significant differences appear between the plots receiving fertilizer treatments. Up to the time of this writing this experiment appeared to be in the same category as those in Pennsylvania and New York where the initial soil fertility was sufficient to maintain tree growth even with considerable fruit production.

The Cultural Experiment.—Turning now to the Cultural experiment it may be seen that the different treatments in these plots show as interesting differences in the trunk measurements as in the twig measurements (see Figure 3). The data on trunk circumferences are included in Table 11.

Delicious with a legume cover crop in Plot 1, although light in some seasons, gave a significant increase in trunk circumference over Plot 2, which was seeded to a non-leguminous crop each year (79:1). Wealthy, on the other hand did not show such an increase (3:1). Stable manure, in Plot 3, which was cultivated, gave no significant increase in trunk circumference over Plot 2, which received no manure, with either Delicious (13:1) or Wealthy (20:1). In Plot 4 (cultivated) acid phosphate and nitrate of soda were not significantly better than was cultivation and a non-leguminous cover crop in Plot 2 with either Delicious (13:1) or Wealthy (21:1). The odds as measured by terminal twig growth were significantly in favor of Plot 4.

There were no significant differences in trunk circumference between cultivation and sod (Plots 4 and 8) when nitrate of soda and acid phosphate were added to both, with either Delicious (7:1) or Wealthy (9:1). When stable manure was added to both instead of nitrate of soda and acid phosphate (Plots 3 and 9), there were significant increases over sod with both Delicious (38:1) and Wealthy (272:1). In Plot 9, manure gave about the same increases in trunk circumference that nitrate of soda and acid phosphate gave in Plot 8. Alfalfa sod was not significantly better than a grass sod in this orchard. Strip-cultivation was not significantly better than alternate row cultivation with either Delicious (18:1) or Wealthy (3:1). An additional mulch around the trees in Plot 11 did not give a significant increase as compared with sod. In alfalfa Plot 7, Wealthy made a better showing than did Delicious, but as noted in connection with twig growth the alfalfa sod was not thick enough in the last few years to make a fair comparison with sod.

TABLE 11.—Effect of Treatments on Trunk Circumference in the Cultural Experiment.

Plot	Treatment	Average Increase in Inches										Total		Average		Odds in Favor of Treatment	
		1919		1920		1921		1922		1923							
		Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy
1	Cultivation and legume cover crop	1.5	1.0	1.5	1.2	1.9	2.2	2.0	1.9	1.2	1.6	8.1	7.9	1.6	1.6	155:1	541:1
2	Cultivation and non-legume cover crop	1.1	1.2	1.1	1.2	1.7	1.9	1.6	1.8	1.2	1.4	6.7	7.5	1.3	1.5	78:1	1666:1
3	Cultivation, non-legume cover crop, and manure	0.9	1.4	1.3	1.1	2.1	2.7	2,2	2.2	1.4	1.7	7.9	9.1	1.6	1.8	50:1	399:1
4	Cultivation, non-legume cover crop, acid phosphate, and nitrate	0.9	1.0	1.1	1.3	2.0	2.4	2.2	1.9	1.2	1.6	7.9	8.2	1.6	1.6	28:1	458:1
5	Sod, alternate row cultivation, and non-legume cover crop	0.7	1.2	1.0	1.0	1.2	1.2	1.6	1.6	1.0	1.0	5.5	7.0	1.1	1.4	16:1	209:1
6	Sod and strip cultivation	0.9	1.0	1.0	1.0	1.7	1.5	1.6	1.6	1.3	1.2	6.5	6.3	1.3	1.3	49:1	746:1
7	Alfalfa sod	0.6	0.8	1.0	0.9	1.4	1.4	1.3	1.1	0.9	1.1	5.2	5.3	1.0	1.1	13:1	9000:1
8	Sod, nitrate, and acid phosphate	0.9	1.2	1.1	0.9	1.9	1.8	1.5	1.2	1.1	1.7	6.5	6.8	1.3	1.4	26:1	675:1
9	Sod and manure	0.8	0.5	1.1	0.6	1.5	1.6	1.6	1.7	1.3	1.3	6.3	5.7	1.3	1.1	60:1	37:1
10	Sod	0.6	0.4	0.9	0.5	0.7	0.8	0.8	0.5	1.0	0.6	4.0	2.8	0.8	0.6		
11	Sod and additional straw mulch	1.0	1.2	1.0	0.7	1.6	1.6	1.4	1.1	0.2	0.0	5.2	4.6	1.0	0.9	3:1	7:1
12	Alfalfa sod	0.7	0.8	1.1	0.7	0.7	1.1	2.0	0.4	0.7	0.5	5.2	3.5	1.0	0.7	4:1	7:1

Size of Tree

Measurements of tree size were made in the Sleepy Creek Experiment in the fall of 1923, in the Rome Experiment in the fall of 1924, and in the Cultural Experiment in the spring of 1925. It was thought that the size of the trees in the different plots would be a good measure of the end result of the treatment and that it would also serve as a check in studying the other growth records. Breadth of tree was measured with a cloth tape and height of tree with a stadia rod. Since these measurements showed that most of the trees approximated a half sphere, the volume was computed using the formula $V=4/3\eta R^3$ where V equals the volume of the sphere.

The St. Marys Experiment.—In the St. Marys Experiment tree size was greatly increased by the nitrate of soda applications as shown in Table 12, the average volume of tree being from two to three times that in the check plots (see Figure 4 on front cover). It will be shown later that such differences in size have a bearing upon fruitfulness. Plot 6, to which potash and acid phosphate were applied, had an average tree size about the same as that of the adjacent check, (Plot 5). This is surprising in view of the increased growth of grass and clover that resulted from the use of phosphate. The nitrogen deficit in this soil was very large and apparently the amounts being added by the clover over the ten year period were not sufficient to affect the size of the tree. Differences in tree size between the plots receiving nitrogen may be attributed to variations in initial soil fertility.

TABLE 12.—Effect of Fertilization on Tree Size in the St. Marys Experiment (1924).

Plot Number	2	3	4	5	6	7	8	9	10
Treatment	N P K	N P	N K	Check	P K	N P K	N P	N K	Check
Average Volume of Top (cu. ft.)	6707	6639	6267	4061	3674	5649	5445	4861	2026

The Sleepy Creek Experiment.—In Table 13 are given the tree sizes in the Sleepy Creek Experiment. The values are not averages, but are the actual tree volumes in cubic feet computed from measurements taken in the fall of 1923. Student's method was used again to determine whether or not any of the fertilizer treatments significantly increased the size of tree. Results, in general, corroborate those from terminal twig and trunk circumference measurements. None of the treatments consistently increased the size of the trees. It will be noticed that a wide variation existed in tree size even in the same plot. This would indicate that factors other than the treatments, such as soil variability, root injury, and possibly a stock relationship, were also influencing tree growth. A number of pictures were taken of trees believed to have been injured by root cutting. One of these trees is shown in Figure 5. At the time this picture was taken on July 25, 1925. the leaves were smaller and many were falling on the side where deep cultivation had been practiced.

Fig. 5.—Tree Injured by Root Cutting in Sleepy Creek Experiment.

The Cultural Experiment.—The effects of the different soil and fertilizer combinations on tree size in the Cultural Experiment are given in Table 14. See also Figures 6, 7, 8, and 9. Comparisons were made of the different treatments by computing the average or mena tree volume in cubic feet. The probable error of the mean

TABLE 13.—Effect of Fertilization on Tree Size in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Tree Volume in Cubic Feet for Trees Numbered					Odds in Favor of Treatment	Odds in Favor of Check
			1	2	3	4	5		
Grimes	1	Check	5268	7501	4496	5116			
	2	N P	6928	8740	8579			188:1	
	3	N K	6518	5385	6254	8740		6:1	
	4	N P K	4601	6518	6789	4189		2:1	
	5	P K	9070	5153	8904	5039	8904	16:1	
	6	Check	3354	4927	7799	4927			
	7	N	5747	8904	7649		5385	8:1	
	8	P	8904	2223	6789	4290	2638	even	
	9	K	6695	3803	2566	5039	4601		2:1
	10	Check	13047	3185	3619	3354	1796		
Ben Davis	1	Check	2494	2864	2943	2424	3619		
	2	N P	6124	5268	5153	12626	6518	32:1	
	3	N K	5747	5385	6653		8105	98:1	
	4	N P K	4708	4817	3993	7649	11812	8:1	
	5	P K	4290	2032	5153	8419	3993	even	
	6	Check	3103	5385	7649	5153	4817		
	7	N	6124	4601	1103	7649	6124	even	
	8	P	3803		4290	3529	7355	even	
	9	K	2788	4601	2788	4392	4927		2:1
	10	Check	3022		3529	4091	4496		
York	1	Check	7649	6789	4392	3993	5997		
	2	N P	8419	4189	5997	4817	6518	even	
	3	N K	6928	6254	6653	6254	4496	even	
	4	N P K	4927	5153	6124	7799	8579	21:	
	5	P K	4091	4927	2223	3993	4290		54:1
	6	Check	7951	5997	6124	4290	6124		
	7	N	5385	10657	8579	8419		9:1	
	8	P	5153	4290	1527	2424	3441		103:1
	9	K	4927	2638	1971	3354	2032		40:1
	10	Check		3803	3803	4817	8419		

was determined by using Bessel's formula. The average size of trees as indicated by trunk circumference and twig growth was greater in all plots which received fertilizer or cultural treatments than it was in the untreated or sod plot. The different treatments were also compared using the probable error of the difference.* When a legume cover crop was compared with a non-legume cover crop by this method (Plots 1 and 2) a significant increase in average tree size was shown with Wealthy (142:1) but not with Delicious (2:1). Anthony and Waring (1925) in Pennsylvania, with sixteen year old Stayman, found a significant increase in growth with a leguminous over a non-leguminous cover crop. Stable manure gave a significant increase in tree size in Plot 3 over Plot 2 with Delicious (267:1), but not with Wealthy (22:1). Annual cover crops of rye were sown

*This is found by taking the square root of the sum of the squares of the probable errors of the two results. To secure odds of 30:1 indicating that the difference is due to something other than chance, the difference must be slightly greater than three times its probable error.

Fig. 6.—Average Tree in Cultivated Plot 4 Fertilized with Nitrate and Acid Phosphate.

Fig. 7.—Average Tree in Cultivated Plot 2 Not Fertilized.

Fig. 8.—Average Tree in Sod Plot 8 Fertilized with Nitrate and Acid Phosphate.

Fig. 9.—Average Tree in Sod Plot 10 Not Fertilized.

on both plots. In Plot 4, however, which received annual applications of nitrate of soda and acid phosphate, there was no significant increase in average tree size over the average size in Plot 2 in the case of either Delicious (14:1) or Wealthy (5:1). Trees in Plot 6, which had a twelve foot strip in the row cultivated were not significantly larger than trees in Plot 5 which was given alternate row cultivation. Manure in Plot 9 and nitrate of soda and acid phosphate in Plot 8 (both in sod) strikingly increased the average size of tree as compared with Plot 10 which was in sod but did not receive any fertilizer. The trees on each of the fertilized cultivated plots obtained an average tree size significantly larger than the average in either sod Plot 8, which received nitrate of soda and acid phosphate, or sod Plot 9, which received manure. There were no significant differences, however, when tree size in the fertilized sod plots was compared with that in Plot 2, which was cultivated and had an annual cover crop of rye but was never fertilized.

TABLE 14.—Effect of Treatments on Tree Size in the Cultural Experiment.

Plot	Treatment	Average Volume of Tree in Cubic Feet	
		Delicious	Wealthy
1	Cultivation and legume cover crop	1500±108	1301±67
2	Cultivation and non-legume cover crop	1299±58	887±76
3	Cultivation, manure, and non-legume cover crop	1759±89	1307±121
4	Cultivation, nitrate, phosphate, and non-legume cover crop	1618±102	1133±81
5	Sod and alternate row cultivation	813±76	639±57
6	Sod and strip cultivation	975±92	829±73
7	Alfalfa sod	760±37	597±44
8	Sod, nitrate, and acid phosphate	1045±73	916±112
9	Sod and manure	850±109	784±53
10	Sod	244±20	441±40
11	Sod and additional straw mulch	Discarded	Discarded
12	Alfalfa sod	497±63	474±73

EFFECT OF FERTILIZERS AND CULTURE ON FRUITFULNESS

In the preceeding section attention has been directed to the influence of the different variables in the treatment upon tree growth. A particular treatment may increase the growth of a tree but if it is

not accompanied by increased yield, either actually or potentially, it is of questionable value from the practical standpoint. The influence of the different treatments upon fruitfulness was studied in these experiments by bloom, set and yield, and color and size of fruit. They are taken up here in the order given.

Bloom and Set

The St. Marys Experiment.—Table 15 includes the bloom and set records in the St. Marys experiment for the past three years. In Bulletin 174, it was shown that over a period of four seasons the bloom in the nitrated plots was somewhat heavier than in the other plots. The amount of bloom was figured for each tree (Table 15) and these amounts were then averaged for the plot. In the spring of 1918 when the bloom was heavy, actual counts were made of flowers at bloom. From these counts the set was obtained after the "June drop". That year in the nitrated plots receiving acid phosphate the set was 5.16 to 6.66 per cent of the total bloom, while in the check and nitrated plots receiving potash the set was 3.08 and 3.25 per cent, respectively. Acid phosphate and potash in Plot 6 did not increase the set (2.98 per cent) over that of the check.

TABLE 15.—Effect of Fertilization on Bloom and Set in the St. Marys Experiment.

Plot	Treatment	Per Cent Bloom			Per Cent Set		Per Ct. Set
		1922*	1923	1924	1923**	1924†	1923††
2	N P K	86.3	58.2	19.6	54.3	25.0	18.2
3	N P	78.6	57.0	20.9	56.1	20.4	27.6
4	N K	75.0	53.6	31.0	63.6	13.2	25.5
5	Check	59.8	29.3	28.8	45.0	16.8	14.2
6	P K	76.0	20.2	29.4	38.2	8.5	13.9
7	N P K	82.2	57.0	22.1	56.3	19.7	23.6
8	N P	85.2	60.0	19.4	56.6	31.0	36.5
9	N K	68.9	38.8	37.6	60.0	14.0	30.6
10	Check	46.2	12.4	27.9	35.5	7.8	15.1
Average Nitrogen Plots		79.3	54.5	24.1	57.6	19.8	26.3
Average Minus Nitrogen Plots		60.7	20.6	28.6	40.7	11.2	15.4

*Blossoms killed in bloom.
**Count made on May 22.
†Count made on June 6; no later count made.
††Count made on June 22.

In the years 1922 to 1924, inclusive, the set was studied by still another method. In determining the "per cent of bloom", in Table 15, representative limbs were selected, tagged, and the total number of growing points, both terminals and spurs, counted. The number of these growing points bearing flowers was then obtained. The

per cent of bloom was then computed from these two values for each limb, tree and plot. The per cent set was obtained later by counting the spurs and terminals which had set one or more fruits and was figured in terms of blooming growing points.

In studying the data in Table 15, it may be seen that bloom and particularly the set was increased by the nitrate applications. In the check plots even when the bloom was light most of the flowers fell. Where muriate of potash and acid phosphate were added (Plot 6) neither the bloom nor set was influenced appreciably. Considering the increase in the size of the trees and the increased bloom and set in the nitrated plots when compared with the checks, it is evident that these differences came about as a result of the nitrate applications, a fact which has an important bearing upon production.

In addition to the increase in the bloom and the set, marked differences were also noticeable in the blooming period in this experiment. While flowers began to open at about the same time on all plots, the blooming extended over a longer period in the nitrated plots. The extension of this period was primarily a result of the later opening of flowers on long terminals and laterals, of which there were many more in the nitrated plots. Flowers from lateral buds seldom set, however, except when spur and terminal bloom were killed by low temperatures.

The Sleepy Creek Experiment.—It was difficult to secure accurate data on blom and set in this experiment because the bloom was so scattering in each of the three varieties. While records were taken, the great variability encountered each season in the amount of bloom in all plots made it impracticable to analyze the data statistically. Figure 10 is a diagram of the estimated bloom of each tree in the Grimes block of the experiment for 1924. Broken lines surround areas in tops while solid lines surround areas in lower parts of trees.

The trees in the plots of the other varieties showed much the same variability. In some trees the bloom was scattered over the entire tree and in others it was limited to one or more limbs. The fullest bloom recorded on any tree in the block for the year was 70 per cent. Four trees did not bloom. The bloom record was taken in this manner only the one year, but in previous years also bloom was irregular and scattering. It is evident that this condition would have a direct bearing upon production and this should be kept in

Fig. 10.—Per Cent Bloom (1924) of Trees in Grimes Block, Sleepy Creek Experiment.

mind in studying the yields. The factors entering into this abnormal situation will be discussed in more detail later.

The Cultural Experiment.—The trees in the Cultural experiment were just beginning to bear in 1924. Under the conditions of the experiment, Wealthy came into bearing earlier than Delicious, although planted alternately with it. A few of the Wealthy trees bloomed in 1923, but in 1924 both varieties had what might be called a scattering bloom, with more on Wealthy. The flowers on Wealthy were nearly all axillary with a few terminal on the longer growths, while on Delicious the bloom was on spurs. Contrary to what might have been expected, the cultivated part of the orchard produced the more bloom. It was interesting to note the amount of the bloom on Wealthy in the cultivated plots just as the trees were coming into bearing: In Plot 1, the average number of flowers per tree was forty-two; in Plot 2, fifteen; in Plot 3, 105; and in Plot 4, thirty-five. The bloom was scattering on Delicious in the cultivated plots. In sod Plots 8 and 9, the bloom was still lighter, and it was only scattering on the other trees of the experiment. This early bloom set fruit and showed an interesting tendency in this experiment.

Yield and Size

The yield records were taken each crop-year in either bushels or pounds. In the earlier report (Bulletin 174) some attention was also given to color under the different treatments, but since then the records were limited to quantity and size of fruit. Because the trees are just coming into bearing in the Cultural Experiment, yield records for this experiment are not included in this report.

In general, it may be said that yield is not as consistent a criterion to use in gauging the effects of different treatments in an orchard as is growth or even bloom, because the crop is so often reduced by frosts, freezes, hail, drouth, or fungus diseases and insect injury. The results from any plot experiments are also of necessity influenced by the condition of the orchard. Nevertheless, since the success of an orcharding enterprise must in the end be measured by yield, the production in the different treatments in these experiments is recorded here regardless of the irregularities in the crops from year to year.

TABLE 16.—Effect of Fertilization on Yield of Fruit in the St. Marys Experiment.

Plot	Treatment	Yield in Bushels*										Total Yield
		1912	1914	1915	1916	1917	1918	1919	1920	1923	1924	
2	N P K	57.30	31.60	127.40	34.00	74.70	131.40	96.25	87.00	153.25	23.00	815.90
3	N P	42.00	16.80	128.00	31.70	92.50	145.50	124.25	101.00	131.86	27.10	840.71
4	N K	49.50	14.50	110.50	51.40	59.50	137.50	73.00	101.00	100.03	26.50	723.43
5	Check	42.00	15.50	87.50	40.00	24.50	54.80	46.25	36.00	17.58	4.04	368.17
6	P K	41.70	12.80	82.40	46.00	24.70	54.50	34.25	50.00	20.66	2.02	369.03
7	N P K	49.10	19.10	92.70	65.70	66.50	105.80	72.50	92.50	118.80	13.10	695.80
8	N P	66.00	18.30	124.30	83.20	90.30	158.80	96.50	126.00	96.96	14.46	874.82
9	N K	46.50	9.30	78.80	48.30	48.60	91.50	51.50	90.50	70.20	18.00	553.20
10	Check	39.30	9.60	71.20	45.30	22.60	39.50	31.25	25.75	8.28	1.38	294.16

*Crops destroyed by frosts in 1913, 1921, and 1922.

The St. Marys Experiment.—In Table 16 the yields in the St. Marys experiment are summarized for a twelve year period. It will be noted that the crop was destroyed by frosts three times during this period, two of which occurred in succession.

In studying this table it may be seen that the nitrate applications had a marked and consistent influence on yield. On the other hand, muriate of potash and acid phosphate (Plot 6) were seemingly ineffective in increasing the yield. In both checks and the potash-phosphate plot there was an increase in production up to the crop year of 1915, but after that there was a constant decline to an extremely low figure in 1924. In 1915, the third year after the rejuvenation program was started, the yield was heavy in all of the plots, but especially so in those receiving nitrate of soda. In comparing the crop of 1915 with that of 1923, it will be seen that while the yield in the nitrated plots was not much different there was a marked decrease in the yield of the checks and Plot 6 which was fertilized with potash and phosphate. This contrast further emphasizes the influence of the nitrogen in maintaining both vigor and production. The total yield in bushels in the nitrated plots gives another measure of this influence over a long period of time.

The Sleepy Creek Experiment.—The general trend of the influence of nitrogen in this experiment was not so clear as in the St. Marys test. Emphasis has already been placed upon the scattered bloom in these plots, so it would hardly be expected that results measured by yield would differ materially from those measured by bloom.

When the yields since 1921 are studied, more uniform differences in favor of the nitrated plots are evident. As has been stated, the nitrate applications were increased in 1921 from 1.5 pounds to three pounds per tree, and in 1922 to four pounds per tree. Still later, in 1923, five pounds per tree were applied, and this amount was again increased in 1924 to six pounds per tree. In spite of the irregularities in soil in this plot and the limits placed upon root activity by shallow soil, erosion, and with some trees root cutting from cultivation, the nitrate applications seemed to be building up, fairly consistently, more productive trees. This was more noticeable with Ben Davis than with Grimes or York. Further consideration is given to this experiment in the general discussion.

The Rome Experiment.—In the Rome Experiment at Sleepy

TABLE 17.—Effect of Fertilization on Total Yield in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Yield in Pounds 1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Total	Odds in Favor of Treatment	Odds in Favor of Check
Grimes	1	Check	*	251	482	83	408	150	715	202	425	995	415	4160		
	2	N P		139	290	147	443	67	496	326	678	1240	1234	5060	10:1	
	3	N K		155	161	102	324	459	430	216	953	662	774	4101	2:1	
	4	N P K		79	155	96	284	141	441	551	789	1176	409	4121	2:1	
	5	P K		256	719	210	749	241	1333	792	1065	1277	716	7358	400:1	
	6	Check		355	533	238	444	184	543	328	370	428	140	3563		
	7	N		342	531	137	646	234	1219	279	1178	845	547	5597	24:1	
	8	P		254	396	156	508	305	623	528	400	807	55	3907		9:1
	9	K		146	332	52	278	70	132	598	125	370	70	2120		312:1
	10	Check		345	600	141	673	217	1372	603	643	860	750	5938		
Ben Davis	1	Check	52	110	109	73	283	31	323	18	97	682	43	1821		
	2	N P	101	260	269	300	1028	208	894	427	359	1813	311	5970	650:1	
	3	N K	152	306	335	319	1569	290	1105	209	360	2050	142	6837	219:1	
	4	N P K	321	449	607	480	1760	190	1359	280	389	2030	206	8071	658:1	
	5	P K	27	98	204	69	903	106	700	122	167	1188	68	3765	8:1	
	6	Check	106	118	241	41	944	151	419	32	237	1042	145	3476		
	7	N	166	407	324	460	1660	230	1156	219	317	1663	63	6665	188:1	
	8	P	202	384	251	140	1371	12	511	42	106	1354	76	4559	8:1	
	9	K	355	482	392	440	1167	44	439	22	108	684	158	4291	195:1	
	10	Check	286	483	325	248	876	40	300	12	32	510	129	3241		
York	1	Check	65	334	16	138	*	1204	38	714	611	1548	483	5151		
	2	N P	26	83	43	332		795	83	401	431	883	598	3675		18:1
	3	N K	249	199	433	445		2267	100	1028	1080	2429	179	8409	68:1	
	4	N P K	95	195	103	708		1694	254	661	1349	1799	1304	8162	114:1	
	5	P K	18	184	80	633		369	20	48	238	456	236	2282		50:1
	6	Check	44	369	443	575		531	45	326	220	946	112	3611		
	7	N	14	184	36	207		595	204	567	227	1021	14	3069	even	
	8	P	25	50	250	135		230	35	265	48	606	24	1668		195:1
	9	K	17	114	103	187		178	34	148	8	308	8	1105		40:1
	10	Check	00	45	20	169		365	62	244	142	900	10	1957		

*No records were secured.

TABLE 18.—Effect of Fertilization on Total Yield in the Rome Experiment.

Plot	Treatment	Yield in Pounds 1918	1919	1921	1924	Total
1	N P	167	39	760	1115	2081
2	N K	16	13	229	783	1041
3	N P K	169	21	203	998	1391
4	P K	6	13	267	1144	1430
5	Check	24	4	160	429	617
6	N	2	5	262	476	745
7	P	46	13	361	730	1150
8	K	6	4	403	429	842

Creek only four crops of fruit were harvested. The yield in pounds for the entire period is given in Table 18.

The results of this experiment, measured in terms of yield, correspond, in general, to those for twig growth or trunk circumference. While all the plots gave an increase in yield over the one check, the responses were so inconsistent that no conclusions can be drawn. Apparently in this particular location the initial reserve of food supply was sufficient, although the possibility of cross-feeding has, as previously noted, made it necessary to discontinue this experiment.

Effect of Nitrogen on Size.—The fruit harvested in the Sleepy Creek Experiment was graded each year. The sizes of the grades are shown in Table 19. For briefness in presentation, the weights in the different grades of the three varieties, Grimes, Ben Davis, and York were thrown together.

None of the treatments consistently increased size. If a still broader grouping is made of all of the varieties into the "nitrogen" and "non-nitrogen" plots, it may be seen that still no consistent increase in size of fruit resulted from the nitrogen applications. When rainfall during the summer months is considered, however, a marked relationship may be discerned between the nitrogen applications and size. This may be best seen by comparing the percentages in the different grades in 1921 with those of 1924.

In 1921 more than seven inches of rain fell during August as compared with less than two inches in 1924 (see Table 20). The fruit in the nitrogen plots was larger in 1921 and smaller in 1924. The increased size of fruit in the plots not receiving nitrogen was very noticeable in 1924 to different observers passing through the orchard. A study of the grades in Table 19, with reference to the rainfall given in Table 20, will show clearly the effect of an ade-

TABLE 19.—Effect of Fertilization on Size of Fruit in the Sleepy Creek Experiment.

Treatment	Number of Pounds of Fruit by Years and Grades														
	1920			1921			1922			1923			1924		
	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—
Check	18	275	783	79	275	581	154	530	499	775	1856	596	216	519	205
N P	92	733	648	114	393	647	99	798	570	1525	1852	559	1259	791	95
N K	64	938	635	52	338	1063	163	1505	724	1184	3406	541	665	379	54
N P K	81	1272	701	180	498	812	126	1439	969	1476	2623	910	1040	817	63
P K	48	716	1289	111	622	228	69	887	514	422	1954	549	439	527	54
Check	21	459	527	39	329	318	54	398	376	368	1376	671	97	254	47
N	90	1238	1251	50	329	687	297	937	488	743	2219	575	429	187	8
P	34	558	577	98	441	296	14	302	236	520	1818	428	34	89	32
K	33	446	126	107	516	145	29	149	65	289	813	259	98	128	10
Check	22	504	1206	104	477	277	44	404	369	422	1542	301	419	406	63
Per cent of each grade in nitrogen plots	4.3	53.4	42.3	7.7	30.2	62.1	8.5	57.6	33.9	28.0	57.3	14.7	58.6	37.5	3.9
Per cent of each grade in non-nitrogen plots	2.4	38.7	59.0	10.8	52.7	36.5	7.3	52.9	39.8	18.8	62.5	18.7	35.8	52.8	11.4

TABLE 20.—Precipitation During the Summer Months at Martinsburg Weather Station 1920-1924.

Years	Months and Rainfall in Inches		
	July	August	September
1920	2.93	3.68	3.45
1921	2.24	7.59	3.65
1922	5.19	2.31	1.76
1923	3.90	2.92	3.10
1924	2.52	1.76	4.13

quate moisture supply upon size. Even the leaves had a more withered appearance in the nitrated plots during the dry season. Apparently under the conditions of a moisture deficiency the larger leaf area of the nitrated trees was drawing more heavily from the developing fruits than was the smaller leaf area of the non-nitrated plots.

DISCUSSION

The responses in growth and yield that the trees in the four experiments made to the different soil and fertilizer treatments have been presented and commented upon separately. Some of the more general features of these experiments will now be taken up.

In the St. Marys Experiment nitrate applications influenced the trees in three ways: (a) bloom and set of fruit were increased; (b) growth, whether measured by twig extension, increase in trunk circumference, or size of tree, was consistently and significantly increased; (c) the yield was increased. It seems safe to conclude, therefore, since these results agree with those of experiment stations in neighboring states, that growth and fruitfulness in sod orchards will be markedly and profitably increased by nitrogen applications, especially on the less fertile soils.

In contrast to the results in the St. Marys Experiment the trees in the Rome Experiment did not make a significant response to any

of the fertilizer treatments. The orchard was planted on a virgin soil which was more fertile than the soil in either the St. Marys or the Sleepy Creek orchard. The trees in the untreated plots continued to grow vigorously so it is not surprising that they failed to respond to the nitrate applications.

In the Sleepy Creek Experiment as in the Rome Experiment, no treatment consistently had a significant influence on either growth or yield. The nitrated plots had heavier, greener foliage, but tree growth and yield were so variable that the effect of the nitrogen seemingly was masked. This variability is clearly brought out by Figure 1, which shows individual tree yields and trunk circumference increases from the time the experiment was started. A study of this figure shows about as much variability under the same treatment as between treatments. Some of the causes for this variability have already been mentioned and a more detailed discussion of them was given in a previous publication (Dorsey and Knowlton 1924). It is believed, however, that the trend is toward greater growth and better yields in the plots receiving nitrate and, with time, these plots may be expected to forge ahead of the others.

It will be seen, therefore, that more or less marked differences in growth and fruitfulness resulted from the various treatments given in the four orchards under experimentation. In addition to the differences already mentioned there are some more general features in these experiments which should be emphasized.

In the St. Marys experiment the trees in the plots receiving nitrate had heavy, dark green foliage in contrast to the small pale green leaves of other plots. This difference was also noticeable in the Sleepy Creek experiment with Grimes, Ben Davis, and York, but the differences were not so evident as at St. Marys. In the Rome experiment slight differences in foliage color or in leaf-fall could be seen in some years between the nitrated and non-nitrated trees, but not in others.

Theoretically, the increased clover growth in Plot 6 of the St. Marys experiment which received acid phosphate and muriate of potash should have returned sufficient nitrogen to the soil over a ten year period to increase markedly the vigor of the trees. Actually, the color and size of the foliage was about the same as on check Plot 5.

In the Cultural Experiment the trees in the four cultivated plots (1 to 4) and the sod plots (8 and 9) receiving acid phosphate and nitrate of soda or stable manure appeared to be of equal vigor although the trees in the fertilized sod plots were smaller. The trees in the strip-cultivated Plot 6 were more healthy and vigorous than those in the alternate row cultivated Plot 5. The growth of the rye cover crop in Plots 3 and 4 was very luxuriant as compared to the rather weak growth on Plots 1 and 2. It seems probable that this continual returning of organic matter to the soil may ultimately result in a greater tree growth.

In the Cultural Experiment the several treatments were begun when the trees were set out. The results, therefore, should throw some light on orchard soil management up to bearing age. The trees in the unfertilized sod plot made the least growth. At the time of this writing they were in the "old tree" condition with small yellow foliage and weak unfruitful spurs. The adjoining plots fertilized annually with nitrate and acid phosphate, or stable manure, responded in a striking manner to these treatments. Average tree size was increased from two to five times in the seven year period and the trees were beginning to bear at the time of this report. Without doubt these applications of fertilizers will prove to be profitable in the immediate future.

Plot 2, which had cultivation each year with a rye winter cover, made about the same growth as either Plot 8 fertilized with nitrate of soda and acid phosphate, or Plot 9 fertilized with stable manure, both plots being in sod. It is, therefore, a question whether or not it was profitable to cultivate in this orchard. The trees in the cultivated plots grew more rapidly the first few years of the experiment, but in recent years the trees in the fertilized sod plots made as much, and in some cases more, growth than did the trees in the cultivated plots. Undoubtedly the sod mulch, now well established, caused this recent increased growth because of its ability to conserve moisture. Anthony and Waring (1925) noted during a dry season in Pennsylvania that the per cent of moisture in all the sod mulch plots was double that in the soil under cultivation except where a plot was tilled continuously, and even in this plot the soil had only about two-thirds as much moisture as in the grass plots.

Plot 3, cultivated and fertilized with nitrate and acid phosphate, made fairly significant increases in growth over Plot 2, cultivated

but not fertilized. It is doubtful, however, if the increased size was worth the cost of fertilization.

Lack of soil moisture and nitrogen are undoubtedly limiting factors in apple production in West Virginia. On the shallower shale soils the problem becomes more acute. The grower can supply the nitrogen at comparatively small cost by applying either nitrate of soda or sulphate of ammonia, but moisture cannot be supplied so easily. In the territory west of the Allegheny Mountains where the average annual rainfall is 40 to 45 inches, moisture conservation is not so important as in the Eastern Panhandle section where the annual rainfall is 35 to 40 inches and drouths during the growing season are of frequent occurrence. Where it is possible to get growths of grass or clover sufficient to provide a mulch of decaying organic matter several inches thick on the surface, it is probably as effective in conserving moisture as a dust mulch.

The Ohio Agricultural Experiment Station (Ellenwood 1925) has shown that the cost of cultivation and cover crops in a young orchard averages about $15 per acre more annually than the cost of maintenance of a sod mulch without fertilizer. In the Cultural Experiment the cost of fertilization averaged about $10 an acre each year, leaving a balance in favor of the sod mulch system of $5 per acre. Undoubtedly, this balance could be increased by reducing the annual amount of both nitrate and acid phosphate applied without seriously affecting the growth of the grass. While mice may cause some injury to trees under the sod mulch system, less soil erosion occurs, the orchard can be sprayed easier during wet seasons and the fruit can be kept cleaner at picking time than in a cultivated orchard.

These differences in the response of apple trees to different treatments should now be considered in the light of some of the more recent advances in the study of plant nutrition. Vegetative growth and fruitfulness have generally been thought of as being opposed to each other, but the work of Kraus and Kraybill (1918) has, on the contrary, clearly established their interrelation. These investigators postulate certain conditions regarding growth and fruitfulness based on the relative amounts of carbohydrates and nitrogen available to the plant.

A young tree growing vigorously in a soil well supplied with moisture and nitrates has a high nitrogen content and never ac-

quires that surplus of available carbohydrates (sugars and starch) that seems to be essential for fruit bud formation, because under these conditions they are constantly being used in growth. Applications of nitrogenous fertilizers will keep such trees in this vegetative condition and delay fruitfulness. In this instance vegetative growth appears to be "opposed" to fruitfulness. Light thinning out of small branches and treatments that result in moderate growth only will tend to bring about that accumulation of starches and sugars that seems to be essential for fruit bud initiation.

With older trees that have already begun to bear there is more of a balance between available carbohydrates and available nitrogen which permits moderate growth, a carbohydrate surplus, and fruit bud formation. With a marked decline in available nitrogen comes waning vigor, larger accumulations of carbohydrates and unfruitfulness. In practice, apple trees which are bearing good crops of fruit cannot, except by extreme methods, be brought to the vigor of young trees—the vigor that results in too much vegetative growth and too little fruit bud formation. In fact, in most orchards old enough to bear, the trees lack vigor and are unfruitful because of a lack of available nitrogen. In such orchards, treatments like pruning, nitrating, or cultivating promote both growth and fruitfulness. Partridge (1919) found that with Jonathan, Transparent, and Stayman the average yield per tree was correlated with increase in trunk circumference. Similar results are reported by Shaw (1924) who found that increased growth led to more abundant spur formation which in turn produced more fruit buds.

In the experiments herein reported increased growth has generally been followed by increased fruitfulness. This is particularly evident in the St. Marys experiment with Rome. Although no data have been presented, the trend was in the same direction in the cultural orchard—the more vigorous trees beginning to bear first. In a more fertile soil the opposite condition would probably result with these young trees.

Color of fruit was uniformly reduced by the nitrogen applications in these experiments. Mention of this was made in Bulletin 174. While much of this was due to greater shading and to later maturity of the apples they are not the only factors involved. Apples fully exposed to sunlight on vigorously growing trees never acquire the bright lively red color to the same extent and degree that apples

on less vigorous trees do. This was particularly noticeable in 1925 on Wealthy in the cultivated plots of the Cultural Experiment.

Numerous investigators have shown that the carbohydrate content of rapidly growing trees is not as high as that of less vegetative trees. Knudson (1916) and others have noted the close relationship between the sugar content of a plant and pigment production. It would seem, therefore, that the failure of fruit on highly vegetative trees to color well is due in part to the smaller amounts of carbohydrates present from which these red anthocyan pigments are synthesized. If this be true, thinning out the tree will but partially solve the difficulty. The grower, therefore, should be careful not to apply excessive amounts of readily available nitrogen. Experience has also shown that the later in the spring and early summer that these fertilizers are applied, the greater is the deterrent action on color production.

SUMMARY

The West Virginia experiments reported on in this bulletin are four in number. Tree response to the different treatments was determined from growth measurements, set of blossoms and fruit, and from yield records. A brief review of each experiment with the results obtained follows:

The St. Marys Experiment with twenty-year-old Rome trees was started in 1911, to study the effect of different combinations of nitrate of soda, acid phosphate, and potash upon tree behavior. The orchard was cultivated until 1918 when it was seeded to grass and clover. The results to date show marked increases in growth, bloom, set of fruit, and yield from the use of nitrate of soda. Acid phosphate increased cover crop growth only.

The Sleepy Creek Experiment was started in 1913 with nine year old Grimes, York, and Ben Davis. The effect of applications of nitrate of soda, acid phosphate, and muriate of potash, singly and in combination, were studied in this experiment. This orchard was cultivated and sown to annual cover crops. Nitrogen applications seemingly benefited the trees, but due to soil variability, root cutting, and possibly a stock-cion relationship no consistently significant differences between the different treatments were evident.

The Rome Experiment with one year old Rome trees was begun in 1911. Cultivation with annual cover crops was practiced during the duration of the experiment. The plan was similar to the plan

of the one at Sleepy Creek. None of the treatments consistently influenced either growth or yield. The soil in this orchard was more fertile than the soil in any of the other experimental orchards.

The Cultural Experiment was begun in a newly planted block of Delicious and Wealthy in 1917 and had for its object a study of some of the different systems of orchard management practiced in West Virginia. Arranging the different treatments in ascending order according to total amount of tree growth resulting in the seven year period they stand as follows:

1.—Sod without fertilizer.
2.—Alternate row cultivation.
3.—Strip cultivation.
4.—Sod with stable manure.
Sod with nitrate of soda and acid phosphate.
Cultivation with non-legume cover crop.
5.—Cultivation with stable manure and non-legume cover crop.
Cultivation with nitrate of soda and acid phosphate and non-legume cover crop.

CONCLUSIONS AND RECOMMENDATIONS

Growth and fruitfulness can be maintained in the average bearing apple orchard in West Virginia by cultivation, or by sod together with early spring applications of either nitrate of soda or sulphate of ammonia. Stable manure, if available, may be used instead but it seldom can be obtained in sufficient quantities.

The grower must determine for himself whether or not the trees in his orchard would be benefited by applications of nitrogenous fertilizers. If the terminal growths average six to eight inches and spur growth one quarter to one-half inches or more annually, with large, healthy, dark green foliage, it is doubtful if nitrogen would help. On the other hand if the terminal growth is under six inches with only a few spurs making annual growths of one-quarter inch or more, and the leaves tend to be small and pale green in color, nitrogen is probably needed.

In order to conserve moisture during the growing season soils should have plenty of humus and a surface mulch of either dust or decaying organic material. Cultivation and sod may be considered as two distinct systems of soil management with different treatments in each.

The Cultivated Orchard

Cultivation can be practiced most effectively in orchards which are fairly level and not subject to washing. If much soil erosion occurs it will ultimately result in serious depletion of fertility. In the cultivated orchard soil moisture may be conserved by the dust mulch by preventing growth of weeds, and by keeping up the humus content of the soil by turning under cover crops. Nitrification is greatly increased by better aeration and because of this, additional nitrogen may not be needed, or if needed, can be applied in smaller amounts. It is necessary that the organic content of the soil be maintained if moisture is to be retained and if nitrification is to proceed actively. The organic matter content of the soil can be maintained by turning under cover crops or by the application of stable manure. Various combinations can be used for cover crops. Experience will soon indicate which one is the most profitable in a particular soil type or locality. Rye with vetch will be found most suitable to West Virginia conditions. The cover crop should be sown from the first to the tenth of August. If soil is poor, 400 pounds of acid phosphate per acre should be applied and, in some soils, attention will have to be given to liming. In the spring just before rye-heading, the growth should be disced under. The orchard should then be cultivated often enough to keep weeds down and maintain a dust mulch until it is time to sow the cover crop again.

In the young orchard, intercropping may be practiced to advantage using any of the cultivated crops such as corn, potatoes, or beans. These crops should not be grown close to the trees so that their roots will compete with those of the trees. A winter cover crop should be planted as in the bearing orchard.

The Sod Orchard

Bearing orchards on ground likely to wash should always be left in sod. In the sod mulch orchard the grass or clover should be cut several times a year and either left on the ground as it falls or placed around the trees. This acts as a mulch effective in conserving moisture, and decaying gradually, adds organic matter to the soil. In an Ohio experiment by Ellenwood (1925) the first cutting was raked up around the trees. Nitrates seemingly are always low under sod (Lyon, Heinicke, and Wilson 1923) so that additional nitrogen

in the form of nitrate of soda or sulphate of ammonia should be added to maintain growth and fruit production. As under cultivation, the nitrate or ammonia should be applied around each tree three weeks or so before bloom, starting about two feet away from the trunk and scattering uniformly to a distance of from four to six feet beyond the spread of branches. An application at this time will increase spur growth to a greater degree than if put on later. The amount per tree will vary from three to ten pounds, depending upon the size and vigor of the tree. If the growth of sod is light an application of acid phosphate broadcasted at the rate of about four hundred pounds per acre will help greatly. In the case of a legume sod in acid soils, liming will be of great benefit. It will be several years before sufficient sod growth is obtained to build up a good mulch of organic matter. During this period lessened growth and yield may result. Then as the moisture retaining quality of the mulch begins to operate, growth will increase again, as in the Cultural Experiment reported in this bulletin. Different kinds of sod may be used. Orchard grass has been very satisfactory in the Cultural Experiment. Sweet clover is being used extensively throughout the state. Alfalfa makes an excellent sod where it can be grown satisfactorily.

In a young orchard it is doubtful if the trees should be kept in sod the first three or four years. If the site is such that soil washing will occur, cultivation should be practiced along a strip four or five feet wide on each side of the rows of trees and perpendicular to the slope leaving the center in sod to hold the soil.

Mice may often cause serious damage in the sod orchard. Various methods of control are advocated. Poisoning has given good results. Where mice are not too plentiful a circular hoed area, five feet or more across, around the tree will keep them in check. This should be done in late summer or fall.

Acknowledgements: Experimentation in apple fertilization has been one of the main investigations of the Horticultural Department of the West Virginia Agricultural Experiment Station since 1911. A number of investigators have assisted in carrying on the routine of these experiments from time to time. The St. Marys Experiment and the Rome Experiment, at Sleepy Creek, were laid out by A. L. Dacy in 1911. E. C. Auchter selected the site and started the Sleepy Creek Experiment in 1913. The Cultural Experiment, at the Horticultural Farm, was planned and started in 1917 by W. H. Alderman, E. C. Auchter, and H. L. Crane. J. H. Gourley and J. K. Shaw had charge of the experiments for limited periods. In addition to the above, the following members of the department have assisted in taking records at different times: H. L. Crane, L. I. Knight, Ernest Angelo, K. R. Jeffries, L. Ankrum, and R. C. McDonald.

The Experiment Station and the department are indebted to the following for courtesies and assistance during the progress of these cooperative experiments: Linden and Philip Reynolds of St. Marys, S. H. and M. W. Fulton of Sleepy Creek, and the American Fruit Growers, Incorporated.

LITERATURE CITED

ALDERMAN, W. H. and H. L. CRANE.
1920. THE FERTILIZATION OF APPLE ORCHARDS. W. Va. Agr. Exp. Sta. Bul. 174:1-51.

ANTHONY, R. D. and J. H. WARING.
1922. METHODS OF INTERPRETING YIELD RECORDS IN APPLE FERTILIZATION EXPERIMENTS. Penn. Agr. Exp. Sta. Bul. 173:1-42.

....
1925. FERTILITY IN THE APPLE ORCHARD. Penn. Agr. Exp. Sta. Bul. 192:1-15.

BALLOU, F. H.
1920. ORCHARD REJUVENATION IN SOUTHEASTERN OHIO. Ohio Agr. Exp. Sta. Bul. 339:1-42.

....
1925. FERTILIZING YOUNG APPLE ORCHARDS. Ohio Agr. Exp. Sta. Mo. Bul. 1-2:14-16.

BRADFORD, F. C.
1924. NITROGEN-BEARING FERTILIZERS AND THE BEARING HABITS OF MATURE APPLE TREES. Mich. Agr. Exp. Sta. Spec. Bul. 127:1-32.

CHANDLER, W. H.
1925. FRUIT GROWING. Houghton Mifflin Company. 770 pp.

COLLISON, R. C.
1920. A PROGRESS REPORT OF FERTILIZER EXPERIMENTS WITH FRUITS. N. Y. Agr. Exp. Sta. Bul. 477:1-53.

.... and J. D. HARLAN.
1923. FINAL REPORT ON THE COOPERATIVE EXPERIMENTS IN ORCHARD FERTILIZATION. N. Y. Agr. Exp. Sta. Bul. 503:1-30.

COOPER, J. R.
1920. PRELIMINARY REPORT ON THE EFFECT OF FERTILIZERS IN APPLE ORCHARDS IN THE OZARK REGION. Proc. Am. Soc. Hort. Sci. 1920:190-193.

DORSEY, M. J. and H. E. KNOWLTON.
1924. PERFORMANCE RECORD OF APPLE TREES OVER A TEN YEAR PERIOD. Proc. Amer. Soc. Hort. Sci. 1924:337-342.

ELLENWOOD, C. W.
1925. COST OF GROWING APPLE TREES UNDER TILLAGE AND GRASS-MULCH MANAGEMENT. Ohio Agr. Exp. Sta. Mo. Bul. 1-2:7-13.

GOURLEY, J. H.
1919. SOD, TILLAGE AND FERTILIZERS FOR THE APPLE ORCHARD. N. H. Agr. Exp. Sta. Bul. 190:1-40.

HEDRICK, U. P.
1924. A COMPARISON OF TILLAGE AND SOD MULCH IN AN APPLE ORCHARD. N. Y. Agr. Exp. Sta. Bul. 383:249-281.

.... and R. D. ANTHONY.
1919. TWENTY YEARS OF FERTILIZERS IN AN APPLE ORCHARD. N. Y. Agr. Exp. Sta. Bul. 460:71-96.

.... and H. B. TUKEY.
1924. TWENTY-FIVE YEARS OF FERTILIZERS IN A NEW YORK APPLE ORCHARD. N. Y. Agr. Exp. Sta. Bul. 516:1-28.

HEINICKE, A. J.
1917. FACTORS INFLUENCING THE ABSCISSION OF FLOWERS AND PARTIALLY DEVELOPED FRUITS OF THE APPLE. (PYRUS MALUS L.) Cornell Agr. Exp. Sta. Bul. 393:1-114.

KNUDSON, L.
1916. INFLUENCE OF CERTAIN CARBOHYDRATES ON GREEN PLANTS. Cornell Agr. Exp. Sta. Mem. 9:1-75.

KRAUS, E. J. and H. R. KRAYBILL.
1918. VEGETATION AND REPRODUCTION WITH SPECIAL REFERENCE TO THE TOMATO. Ore. Agr. Exp. Sta. Bul. 149:1-90.

LEWIS, C. I., REIMER, F. C. and BROWN, G. G.
1920. FERTILIZERS FOR OREGON ORCHARDS. Ore. Agr. Exp. Sta. Bul. 166:1-48.

LOVE, H. H.
1924. A MODIFICATION OF STUDENT'S TABLE FOR USE IN INTERPRETING EXPERIMENTAL RESULTS. Jour. Am. Soc. Agr. 16:68-73.

LYON, T. L., HEINICKE, A. J. and WILSON, B. D.
1923. THE RELATION OF SOIL MOISTURE AND NITRATES TO THE EFFECTS OF SOD ON APPLE TREES. Cornell Agr. Exp. Sta. Mem. 63:1-25.

MORRIS, O. M. and LARSEN, ROY.
1921. ORCHARD SOIL MANAGEMENT AND FERTILIZATION. Wash. Agr. Exp. Sta. Pop. Bul. 121:1-23.

OSKAMP, J.
1920. ORCHARD COVER CROPS. Perdue Agr. Exp. Sta. Bul. 248:1-44.

PARTRIDGE, N. L.
1919. GROWTH AND YIELD OF APPLE TREES. Proc. Amer. Soc. Hort. Sci. 1919:104-109.

RALSTON, G. S.
1921. EFFECT OF TIME OF APPLICATION OF NITROGENOUS FERTILIZERS ON TREE GROWTH, BLOOM, AND FRUIT PRODUCTION. Proc. Amer. Soc. Hort. Sci. 1921:118-123.

ROBERTS, R. H.
1920. OFF-YEAR APPLE BEARING. Wis. Agr. Exp. Sta. Bul. 317:1-34.

SAX, KARL.
1925. FERTILIZATION OF APPLE ORCHARDS IN MAINE. Me. Agr. Exp. Sta. Bul. 322:1-8.

SHAW, J. K.
1922. EXPERIMENTS IN SOIL MANAGEMENT AND FERTILIZATION OF ORCHARDS. Mass. Agr. Exp. Sta. Bul. 209-33-60.

....
1924. SOD-NITRATE vs. CULTIVATION IN THE APPLE ORCHARD. Proc. Am. Soc. Hort. Sci. 1924:328-337.

STUDENT.
1918. Biometrika 6:1-25.

YEAGER, A. F.
1916. A STATISTICAL STUDY OF THE FRUIT-SPUR SYSTEM OF CERTAIN APPLE TREES. Ore. Agr. Exp. Sta. Bul. 139:78-92.

Bulletin 204 June, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Cultural Experiments With Sunflowers and Their Relative Value As A Silage Crop

Field of Sunflowers on the Agronomy Farm, West Virginia Agricultural Experiment Station, Morgantown.

By

T. E. ODLAND and H. O. HENDERSON

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D.................President of the University
GEORGE R. LYMAN, Ph. D..............................Dean of the College of Agriculture
HENRY G. KNIGHT, Ph. D..............................Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr..............................Agricultural Editor
JOHN C. JOHNSTON..............................Chief Clerk

AGRONOMY

R. J. Garber, Ph. D.
Agronomist

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, B. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

E. C. Stillwell, M. S.
Assistant Animal Husbandman

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

Henry G. Knight, Ph. D. Chemist

R. B. Dustman, Ph. D.
Assistant Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

T. J. Cochran, B. S.
Junior Chemist

DAIRY HUSBANDRY

Ernest L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

Warren Gifford, B. S. Agr.††
Junior Dairy Husbandman

G .M. Trout, M. S.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D. Entomologist

W. E. Rumsey, B. S.**
State Entomologist

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D.
Home Economist

HORTICULTURE

M. J. Dorsey, Ph. D.***
Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

H. E. Knowlton, Ph. D.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

Troy M. Currence, B. S. Agr.††
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Assistant Plant Pathologist

L. H. Leonian, Ph. D.
Assistant Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D.
Associate Soil Technologist

*In co-operation with the U. S. Department of Agriculture, Washington, D. C.
**In co-operation with the State Department of Agriculture, Charleston, W. Va.
***Resigned September 1, 1925.
†In charge of the Maggie Sub-Station, Maggie, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††On leave of absence.

Cultural Experiments With Sunflowers and Their Relative Value As A Silage Crop

One of the chief problems which has always faced the West Virginia farmer is the production of sufficient roughage to winter his livestock. He is interested in any crop which gives promise of producing a larger tonnage per acre of either hay or silage than crops that he is growing.

In the last few years a great deal has been written about sunflowers as a crop for making silage. A number of experiments have been conducted in different states. Some experiment stations as well as individual farmers have reported very satisfactory results with this crop. Others have not found it very satisfactory.

The Montana Experiment Station obtained very high yields of sunflowers in that state.* That station recommends sunflowers as a silage crop on account of their ability to produce a large tonnage in a short season. The Washington Experiment Station also reported favorable results with sunflowers.† This crop is recommended for conditions in that state that are not well adapted for corn.

The Ohio Experiment Station did not obtain as favorable results with sunflowers as with corn.** Larger yields of green material were obtained from sunflowers but in dry matter the corn yielded more than the sunflowers.

The experiments reported in this bulletin were planned in order to attempt to find out if sunflowers might have a possible place as a silage crop under West Virginia conditions.

In 1919 a preliminary trial of sunflowers as a silage crop was made by the Dairy Department of the Experiment Station. A plot was planted to this crop and a feeding trial conducted the following winter. A large tonnage per acre was obtained and the feeding qualities appeared to be satisfactory. The results of this test have been published.‡ This preliminary test made it seem advisable to con-

*Jensen, I. J. Sunflowers under irrigation in Montana. Mont. Agr. Exp. Sta. Bul. 162, 1923.

†Schafer, E. G., and Westley, R. O. Sunflower production for silage. Wash. Agr. Exp. Sta. Bul. 162, 1921.

**Thatcher, L. E. Sunflowers for silage in Ohio. Ohio Agr. Exp. Sta. Monhtly Buls. 75 and 76, 1922.

‡Anthony, Ernest L., and Henderson, H. O. Sunflowers vs. corn for silage. West Va. Agr. Exp. Sta. Cir. 32, 1920.

duct more detailed studies with sunflowers as a silage crop. Experiments were accordingly started on both the Agronomy and Dairy farms in 1921 and 1922. The results obtained in these experiments are reported in this bulletin.

EXPERIMENTAL WORK

Methods Used

In the spring of 1922 a series of forty four plots was laid out on the Dairy farm for the purpose of securing more information in regard to the relative value of sunflowers and corn for silage produced under local conditions. The experiment was also planned with a view to finding the best cultural methods to use in growing sunflowers. This test included Cocke's Prolific, a variety of corn representing the late or silage type, and Leaming, a variety representing the type of corn generally grown for grain. Two mixtures of corn and sunflowers were used. In one mixture one sunflower plant alternated with two of corn and in the other mixture there were equal numbers of corn and sunflower plants. All corn and sunflowers were planted in rows 3 1-2 feet apart. The corn alone and the corn and sunflower mixtures were thinned to one plant every fourteen inches. The sunflowers alone were thinned to various spacings in the row ranging from a plant every three inches to a plant every twenty-one inches. The seed was sown thickly and the plants later thinned to the desired stands. Two later plantings of sunflowers were also made in 1922 and 1923. One planting was made each of these years on June 1 and another on June 10. In 1924 no later plantings were made due to the lateness of the season.

Each plot was repeated three times so that there were four plots each year of each treatment or crop. The plots were eight rods in length and four rows wide. An ordinary two-row corn planter was used for planting both the corn and sunflowers. At harvest time the entire four rows were cut and then weighed on a platform scale at the barn before being put through the silage cutter. A sample of about fifteen pounds was taken from each different series of four plots at the time of cutting for the purpose of determining the moisture content and for making a chemical analysis. This sample was weighed at the time it was taken and again after drying. The sample was dried in an artificially heated drying house where it was left until thoroughly dry. It was then taken out and allowed to hang in a shed until it had attained a relatively constant weight when it was again weighed to determine the amount of air dry material.

The samples contained on an average from 7 to 10 per cent of moisture at the time of taking the air dry weights. By taking care to do this weighing after several days of dry weather it was found that the percentage of moisture in the samples became uniform enough to reduce the error resulting from the fluctuation in moisture content of the air within narrow limits. From the dry weights thus obtained the air dry yields per acre were calculated.

After the air dry weights had been obtained the samples were used for making a chemical analysis.*

The plots were cut at only two different times in order to make the work fit into the regular silo filling operations on the farm. It would have been more desirable if several cuttings had been possible so that each series of plots could have been cut when they had reached the proper stage. The first cutting was made at the time the sunflowers planted first were nearly all in full bloom and some of the seeds had reached the light dough stage. At this time the various plots of sunflowers planted alone were cut. In 1922 and 1923 the mixtures of sunflowers and corn were also cut at this time. In 1924 the mixtures were left until the second cutting on account of the very immature condition of the corn.

The second cutting was made when the silos were being filled from the other corn grown on the farm. This corresponded in the two first years with the time the Leaming in the test was ready to cut for silage. In 1924 both varieties of corn were immature when put into the silo. At this time the later plantings of sunflowers were also cut.

In the spring of 1922 an experiment with different rates of planting sunflowers was started on the Agronomy Farm. In this test the same rates of planting were used as on the Dairy Farm. The different plots were repeated in the same way as in the other experiment so that there were four plots of each rate of planting every year.

Mammoth Russian sunflowers were used in all the experiments both on the Dairy and Agronomy farms. The two varieties of corn used in the experiment on the Dairy Farm and also sunflowers were included in the regular corn variety test which was conducted on the Agronomy Farm. The plots here were in triplicate. The corn and sunflowers were planted in rows three and a half feet apart and with plants fifteen inches apart in the rows. Yield determinations

*The authors wish to acknowledge their indebtedness to T. J. Cochrane and T. B. Leith of the Agricultural Chemistry Department for making the chemical analyses.

were made as in the other tests but based only on the two central rows of the plot. The corn was cut when it had reached the glazed stage and the sunflowers when they were nearly all in full bloom.

In making the calculations for yields of the different plots the probable errors of the experiment were also determined* In experimental work this is necessary in order to determine whether differences obtained between different plots are large enough to be significant. The probable errors of the different experiments are shown in the appendix.

Experiments on the Dairy Farm

Table I shows the average yield of sunflowers and corn obtained on the Dairy Farm. Both the average yield of green corn and air dry material per acre are given. The date of planting, of harvesting, and the number of days in the growing period are shown.

The three-year period over which this test extended included two years (1922 and 1923) which represented more or less normal seasons while the other year (1924) was a very abnormal season with a late wet spring and a cool growing season. It was impossible to get the field prepared and the planting done until June 11 or approximately three weeks later than usual. The results obtained should therefore be considered with these facts in mind.

In considering the yield in green forage per acre of the different plots for 1922 as shown in Table I, it is apparent that with the exception of the later plantings made on June 1 and June 10, the sunflowers planted alone out-yielded both varieties of corn. However when the yield on an air dry basis is considered the above order is reversed. The reason for this is due to the higher moisture content of the sunflowers as compared with corn. From the yields of green and air dry material it may be seen that the moisture content of the sunflowers varied considerably between the different rates and dates of planting. It is difficult therefore to draw any conclusions as to the yield of dry matter per acre as based on the green weights without taking the moisture percentage into consideration.

In 1923 the yield of green corn was somewhat higher than in 1922 while the yield of green sunflowers was less than the previous year. The yields on an air dry basis however did not show a very great difference for the various plots for the two years. Again this shows the necessity of taking the moisture content of the green material into consideration.

*The authors are indebted to B. L. Wade, a graduate assistant, for aid in making the calculations.

...lowers and Corn for Silage and Days of Growing Period on the Dairy Farm.

Nature of Plot	Spacing of Plants in Rows (inches)	Date Planted	Date Cut	Days Growing Period	Yield in Tons per Acre		Average Yield in Tons per Acre	
					Green	Air Dry	Green	Air Dry
1922								
Cocke's Prolific Corn	14	5/20	9/13	116	11.96	3.42		
Leaming Corn	14	5/20	9/13	116	8.75	3.10		
Corn ½, Sunflowers ½	14	5/20	8/30	103	14.38	2.57		
Corn ⅔, Sunflowers ⅓	14	5/20	8/30	103	13.20	2.19		
Sunflowers alone	3	5/20	8/30	103	18.00	2.32		
Sunflowers alone	7	5/20	8/30	103	17.35	2.38		
Sunflowers alone	10	5/20	8/30	103	17.09	2.36		
Sunflowers alone	14	5/20	8/30	103	15.32	2.47		
Sunflowers alone	21	5/20	8/30	103	14.44	2.14		
Sunflowers alone	7	6/1	9/13	105	12.33	2.65		
Sunflowers alone	7	6/10	9/13	95	8.78	1.83		
1923							**1922 and 1923**	
Cocke's Prolific Corn	14	5/23	9/14	114	14.85	3.68	13.41	3.55
Leaming Corn	14	5/23	9/14	114	11.08	3.12	9.92	3.11
Corn ½, Sunflowers ½	14	5/23	9/7	107	11.72	2.54	13.05	2.56
Corn ⅔, Sunflowers ⅓	14	5/23	9/7	107	11.59	2.67	12.40	2.43
Sunflowers alone	3	5/23	9/7	107	12.99	2.48	15.50	2.40
Sunflowers alone	7	5/23	9/7	107	12.32	2.32	14.84	2.35
Sunflowers alone	10	5/23	9/7	107	12.32	2.11	14.71	2.24
Sunflowers alone	14	5/23	9/7	107	11.87	2.15	13.60	2.31
Sunflowers alone	21	5/23	9/7	107	11.08	1.98	12.76	2.06
Sunflowers alone	7	6/1	9/14	106	7.67	1.53	10.00	2.09
Sunflowers alone	7	6/10	9/14	96	11.63	2.11	10.21	1.97
1924							**1922-23-24**	
Cocke's Prolific Corn	14	6/11	9/22	103	8.56	1.63	11.79	2.91
Leaming Corn	14	6/11	9/22	103	7.12	1.49	8.98	2.57
Corn ½, Sunflowers ½	14	6/11	9/22	103	11.15	2.19	12.42	2.43
Corn ⅔, Sunflowers ⅓	14	6/11	9/22	103	10.37	1.91	[illegible]	2.26
Sunflowers alone	3	6/11	9/6	87	11.87	1.66	14.29	2.15
Sunflowers alone	7	6/11	9/6	87	11.98	1.87	13.88	2.19
Sunflowers alone	10	6/11	9/6	87	12.13	1.76	13.85	2.03
Sunflowers alone	14	6/11	9/6	87	12.32	1.73	13.17	2.12
Sunflowers alone	21	6/11	9/6	87	11.48	1.56	12.33	1.89
Sunflowers alone	7						10.00*	2.09*
Sunflowers alone	7						10.21*	1.97*

*Two-year average only, for 1922 and 1923.

In 1924 as in 1922 the yields of green sunflowers were somewhat higher on the average than the corn. When the air dry weights were considered the difference was not proportionately as large as in case of the green weights. The mixture of corn and sunflowers as compared with the two crops grown separately, produced a higher yield in 1924 than in the other two years.

Comparing the two types of corn very little difference in yield of air dry material per acre was found when the two varieties were planted and cut at the same time. Cocke's Prolific averaged 2.91 tons of air dry material per acre and Leaming 2.57 tons as an average of the three years. The Cocke's Prolific corn had not reached the same degree of maturity as the Leaming and therefore contained a higher moisture content.

The average yield of green material per acre for the three years with corn and sunflowers growing in a mixture was 12.42 tons where equal numbers of each were grown, and 11.72 tons where two stalks of corn alternated with one of sunflowers. This is a difference of only .70 of a ton per acre. In air dry weights there was a difference of only .17 of a ton. These differences are not large enough to be considered significant. The sunflowers were ready to cut for silage about two weeks before the corn. This made it difficult to determine at what time to cut the mixture for best results.

Considering the various distances at which the sunflowers were spaced in the row there was no significant difference in yield of air dry material per acre for the different spacings. The yields varied from 1.89 tons per acre for the twenty-one inch spacings to 2.19 tons for the plots where the plants were spaced seven inches apart in the row. In green material per acre the yields ranged from 12.33 tons for the twenty-one inch spacing to 14.29 tons for the three-inch spacing. In the three-inch spacing the plants became too spindly. This caused considerable lodging of plants and resulted in much difficulty in cutting. The same was true but to a less extent where the plants were spaced seven inches apart in the row. In the fourteen and twenty-one-inch spacings and particularly in the latter the plants became too large and coarse to make the best silage. The large heads made the plants top heavy and more difficult to handle. The ten-inch spacing gave on the whole the most satisfactory plants for handling.

The two later plantings gave varying results in the two years they were made. The first year the sunflowers planted on June 1 yielded as well on the air dry basis as the earlier plantings. The yield obtained from the June 10 planting was somewhat less on both the green and air dry basis. In the second year these results were reversed. Apparently the seasonal influences were of more importance than the time of planting.

Experiments on the Agronomy Farm

Table II shows the yields obtained with the various rates of planting on the Agronomy Farm.

The thicker plantings, where plants were spaced three and seven inches apart in the rows, produced a little larger tonnage per acre than did the thinner plantings. The difference in yield between the ten, fourteen, and twenty-one-inch spacings were so small that they come within the range of experimental error. The ten-inch spacings produced plants that proved to be the most satisfactory for handling. The three and seven-inch plantings produced plants with stems too small and weak, while the plants in the twenty-one-inch spacing grew too coarse. The plants also had a tendency to become too coarse when spaced fourteen inches apart.

The soil on which the sunflowers were grown on the Agronomy Farm was somewhat lower in fertility than the soil where they were grown on the Dairy Farm. This may explain the somewhat higher yields on the latter farm and may also account for the slightly different results obtained for the various rates of planting.

Table III shows the yields obtained for the four year period, 1921-1924, in which the two varieties of corn and sunflowers were grown in comparison in the regular variety test on the Agronomy Farm.

The average yield of green forage of Cocke's Prolific Corn was only approximately one ton more per acre than the Leaming. The sunflowers outyielded Cocke's Prolific and Leaming corn on the basis of green material by 1.49 and 2.64 tons per acre, respectively. On the air dry basis Cocke's Prolific outyielded Leaming by .53 of a ton per acre and sunflowers by 1.48 tons. The Leaming corn outyielded sunflowers on this basis by .95 of a ton. Expressed in percentages on an air dry basis the yield of Cocke's Prolific showed

TABLE II.—Comparison of Different Rates of Planting Sunflowers for Silage on the Agronomy Farm.

Spacing of Plants in Rows (inches)	1922			1923			1924			1922-23-24	
	Days Growing Period	Yield in Tons per Acre		Days Growing Period	Yield in Tons per Acre		Days Growing Period	Yield in Tons per Acre		Ave. Yield in Tons per Acre	
		Green	Air Dry		Green	Air Dry		Green	Air Dry	Green	Air Dry
3	109	7.49	1.61	104	10.98	1.97	96	11.74	2.25	10.07	1.94
7	109	7.44	1.41	104	11.00	1.94	96	12.40	2.34	10.28	1.90
10	109	7.17	1.44	104	9.41	1.58	96	11.87	1.90	9.48	1.64
14	109	7.05	1.20	104	9.86	1.70	96	10.63	1.84	9.18	1.58
21	109	6.09	1.09	104	9.53	1.50	96	11.61	1.89	9.08	1.49

an increase of 55.2 per cent over sunflowers and an increase of 29.5 per cent over Leaming.

Where the corn varieties were allowed to reach the stage of maturity considered best for silage they outyielded sunflowers by a considerable margin in dry matter per acre.

TABLE III.—Yield of Corn and Sunflowers for Silage on Agronomy Farm 1921-24.

Variety	Year	Days Growing Period	Yield in Tons per Acre	
			Green	Air Dry
Cocke's Prolific	1921	135	9.29	3.19
Leaming		123	6.63	2.63
Sunflowers		107	10.51	2.29
Cocke's Prolific	1922	135	15.72	5.45
Leaming		123	14.24	4.51
Sunflowers		113	18.23	2.91
Cocke's Prolific	1923	142	10.35	3.07
Leaming		130	11.26	3.04
Sunflowers		107	10.33	1.82
Cocke's Prolific	1924	151	9.63	3.30
Leaming		134	8.28	2.71
Sunflowers		106	11.90	2.05
Cocke's Prolific	Average 1921-24	141	11.25	3.75
Leaming		128	10.10	3.22
Sunflowers		108	12.74	2.27

COMPOSITION OF CORN AND SUNFLOWER SILAGE

In 1922 and 1923 chemical analyses were made of samples taken at the time of cutting. The analyses did not differ greatly in the two years for the various plots.

Table IV shows the average composition for these two years. The data show that the average water content of the Cocke's Prolific corn when cut was approximately 75 per cent, of the Leaming 70 per cent, and of the sunflowers 84 per cent. The more immature condition of the Cocke's Prolific corn accounts for its higher moisture content as compared with Leaming. The high moisture content of sunflowers explains why this crop outyielded the corn in some years in green tonnage per acre but yielded less on a dry matter basis.

TABLE IV.—Average Composition of Corn and Sunflowers Cut for Silage on the Dairy Farm 1922 and 1923.

Kind of Silage	Spacing of Plants in Rows (inches)	Constituents (Per Cent)					
		Water	Ash	Protein	Fat	Fiber	Carbo-hydrates
Cocke's Prolific	14	75.16	1.13	1.24	0.38	7.63	22.10
Leaming	14	70.59	1.28	2.07	0.82	5.88	25.25
Corn ½, Sunflowers ½	14	81.96	1.47	1.47	0.58	5.80	14.54
Corn ⅔, Sunflowers ⅓	14	81.76	1.65	1.26	0.62	6.36	14.72
Sunflowers	3	85.05	1.54	1.22	0.65	5.48	11.55
Sunflowers	7	85.03	1.39	1.31	0.71	5.37	11.58
Sunflowers	10	85.87	1.35	1.37	0.54	5.29	10.88
Sunflowers	14	84.28	1.37	1.13	0.57	6.26	12.66
Sunflowers	21	84.91	1.47	1.41	0.75	5.53	11.46
Sunflowers (June 1st)	7	81.00	1.79	1.49	1.43	6.74	14.30
Sunflowers (June 10th)	7	82.28	1.51	1.39	0.85	6.11	13.98
Average Corn		72.88	1.21	1.65	0.60	6.76	23.67
Average Corn and Sunflowers		81.86	1.56	1.37	0.60	6.08	14.63
Average Sunflowers		84.06	1.49	1.33	0.79	5.83	12.34

The corn averaged a little higher in protein and fiber content than the sunflowers but the latter averaged slightly higher than the corn in ash and fat content. The carbohydrate content of corn was considerably higher in all cases than the sunflowers. With the exception of fat content the mixtures of corn and sunflowers were intermediate between the two crops.

Similar analyses were also made of the samples taken from the variety test on the Agronomy Farm. Here the moisture content of the two corn varieties were more nearly alike since they were allowed to reach the same stage of maturity. The moisture content of Cocke's Prolific corn was 69.5 per cent, of Leaming 72.7 per cent and of sunflowers 84.5 per cent. Here as in the analyses on the Dairy Farm the sunflowers showed a high moisture content. In the other constituents the analyses showed percentages very much the same as were obtained in analyzing the samples taken on the Dairy Farm.

DISCUSSION OF RESULTS

In considering the different experiments reported in this bulletin it would seem that where the growing season is normally as long as at Morgantown, 135 to 145 days, a variety of corn that can make use of this length of growing season can ordinarily be depended upon to produce as large a tonnage of green material for silage as sunflowers and a considerably heavier yield of dry matter per acre.

Where the growing season is considerably shorter, as in some of the higher altitudes of the state, so that only an early type of corn will ordinarily mature, sunflowers will probably produce a heavier tonnage of green material per acre and possibly a greater yield on a dry matter basis than corn. Tests should be made with sunflowers for silage under such conditions.

SUGGESTIONS ON SUNFLOWER CULTURE

The following suggestions for growing sunflowers are offered:

Sunflowers should be planted about the time corn is generally planted or a little earlier. Drilling in rows from thirty-eight to forty-two inches apart with plants ten to twelve inches apart in the row will be found satisfactory. Either a regular two-row corn planter or a grain drill with some of the holes closed is well suited for

this work. Approximately five pounds of seed per acre will be required.

The crop should be cultivated the same as corn. Sunflowers shade the ground more completely than corn so that weeds do not thrive as well with this crop as with corn. Where both corn and sunflowers are given the same amount of cultivation the sunflowers are always more free from weeds when the crops are harvested.

For harvesting sunflowers the corn binder is usually satisfactory. Cutting by hand is sometimes necessary where the plants have become lodged.

Sunflowers should be cut before the seeds have reached the hard dough stage. The best guide for determining when to cut sunflowers is probably the time of flowering. The crop should be cut for silage when from 60 to 75 per cent of the plants are in bloom.

SUMMARY

1.—Sunflowers and corn were compared for silage in experiments on the Agronomy and Dairy farms at the West Virginia Agricultural Experiment Station. Different rates and dates of planting of sunflowers were also included. Both silage and grain types of corn were included in the test.

2.—Under the conditions of the experiment on the Dairy Farm, the silage corn and the sunflowers yielded approximately the same average tonnage of green material per acre for the two normal seasons. They both outyielded the grain type of corn on this basis. Both types of corn outyielded sunflowers considerably on the air dry basis, and on this basis there was also a small difference in favor of the silage corn as compared to the grain type. In the short growing season of 1924 the sunflowers outyielded both varieties of corn on the green material basis and also slightly on the air dry basis.

3.—On the Agronomy Farm where both corn varieties were permitted to reach the right stage for silage each year, the sunflowers averaged a little heavier green tonnage per acre but both corn varieties far outyielded them on an air dry basis.

4.—Spacing the sunflowers ten inches apart in the rows gave the best results when both ease of handling and yield were considered.

5—Leaming corn and sunflowers did not prove a satisfactory mixture, chiefly because they do not mature at the same time.

6.—Sunflowers planted at later dates did not give as uniformly good yields as when planted at the same time as corn.

7.—Sunflowers had a considerably higher moisture content than corn. The corn was much higher than the sunflowers in carbohydrate content. The analyses showed only relatively small differences between the two crops in protein, ash, fat, and fiber contents.

APPENDIX

In field experiments such as the ones reported in this bulletin each yield is subject to a probable error. It is recognized therefore that a difference in yield between two plots must be of a certain magnitude before it is safe to consider this difference as significant. The magnitude of the required difference will depend upon the degree of variation among the plots receiving the same treatment. Probable errors were computed for the yields reported in this bulletin in order to determine whether the differences obtained were significant or not.

The method of computing probable errors based on the yield of varieties under test as described by Hayes was used.*

To obtain the probable error of the mean yield of the four plots of each treatment the probable error of a single plot was divided by $\sqrt{4}$. In order to be considered significant a difference should be at least three times its probable error. To obtain a number representing the least significant difference the probable error of the mean was multiplied by $3\sqrt{2}$.

In Table V the probable errors calculated on this basis are shown for each year on the Dairy Farm and for the rate of planting experiment on the Agronomy Farm.

*Hayes, H. K. Controlling experimental error in nursery trials. Jour. Amer. Soc. Agro. 15:177-192. 1923.

TABLE V.—The Probable Error in Percentages for Sunflower Experiments on the Dairy and Agronomy Farms as Measured by the Deviation of Each Plot From the Mean Yield of Each Treatment.

Experiment	Year Grown	Number of Plots	Probable Error in Per Cent	
			Single Determination	Mean
Sunflowers and Corn on Dairy Farm	1922	44	12.1	6.1
	1923	44	9.8	4.9
	1924	36	10.8	5.4
Sunflowers—rate of seeding on Agronomy Farm	1922	20	13.0	6.5
	1923	20	8.4	4.2
	1924	20	8.3	4.2

Student's method was used to determine the significance of the differences obtained in the variety tests on the Agronomy Farm.† When this method is used it is found that the odds are 28 to 1 that the difference in yield between Cocke's Prolific and Leaming corn on the air dry basis is significant. It is usually considered safe to assume that a difference is significant if the odds are as high as 30 to 1.

In the same way the odds are 46 to 1 that the difference in air dry yield between Leaming corn and sunflowers is a real difference. The odds are 77 to 1 that the difference between the air dry yield of Cocke's Prolific corn and sunflowers is significant. In determining the odds the values as given by Love were used.‡

†Student. Probable error of a mean. Biometrika 6:1-25. 1908.

‡Love, H. H. A modification of Student's tables for use in interpreting experimental results. Jour. Amer. Soc. Agro. 16:68-73. 1924.

Bulletin 205

July, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Tomato Late Blight and Its Relation to Late Blight of Potato

(Technical)

By

ANTHONY BERG

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------President of the University
HENRY G. KNIGHT, Ph. D.--------------Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr.---------------------Agricultural Editor
JOHN C. JOHNSTON--------------------------------------Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
T. E. Odland, Ph. D. — Associate Agronomist
D. R. Dodd, M. S. — Assistant Agronomist
T. C. McIlvaine, Ph. D.*† — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, B. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
E. C. Stilwell, M. S. — Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
T. J. Cochrane, M. S. — Junior Chemist
Paul Daughenbaugh — Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
G. Malcolm Trout, M. S. — Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
L. E. Dills, B. S.** — Assistant in Entomology

ZOOLOGY

F. E. Chidester, Ph. D. — Zoologist

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, Jr., M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D. — Home Economist
Nell Nesbitt, A. M. — Home Management Specialist

HORTICULTURE

---------------------- — Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
H. P. Sevy, B. S. Agr. — Assistant in Horticulture
A. L. Tener, B. S. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D. — Associate Soil Technologist

RURAL SOCIOLOGY

T. L. Harris, Ph. D. — Sociologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
**In cooperation with the State Department of Agriculture, Charleston, W. Va
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Tomato Late Blight And Its Relation To Late Blight of Potato

The fungus *Phytophthora infestans* (Mont. De Bary) has been the subject of so many investigations and controversies that it fills one of the most romantic chapters in the history of biological research. Most of these investigations deal with late blight of potatoes, tuber rot, and the much disputed subject of oospore formation.

A review of this phase of the problem is neither necessary nor desirable, as it has been covered repeatedly and adequately by others.

The relation of late blight of tomato to the late blight of potato has always been very much in question. This investigation was undertaken with the object of determining further facts regarding the possible relationship of these two diseases.

HISTORICAL SUMMARY

The occurrence of tomato late blight, caused by *Phytophthora infestans,* was recorded in the literature by Payen (*23*) as early as 1848. Numerous references, to this disease, can be found in the early plant disease literature of Europe.

The first record of the disease in America is perhaps that of Thaxter (*33*) in which he stated: "For some reason not readily explained, tomatoes in various localities have, during the latter portion of last season, been greatly injured by the attack of various fungi, which in 1889 did no special damage to the crop. The most noticeable injury was done by the fungus of the potato rot, (*P. infestans*) which not only attacked the leaves so as to do considerable damage, but appeared with virulence upon green and even partly ripe fruit. . . . Should this taste for tomatoes be perpetuated, it will be necessary to resort to Bordeaux mixture, or carbonate of copper in order to save the September crop. It is unlikely, however, that it will be permanently serious."

Most of the early observers believed that this fungus passed readily from potatoes to tomatoes. W. C. Sturgiss (*32*) referring to *P. infestans* stated: "The fungus which does so much damage to potatoes frequently attacks tomatoes also. Its general effect is the same in both cases, and it may be controlled by the same means." Stone (*30*) said: "Downy mildew of tomato is rarely seen in Massachusetts. It is caused by the same fungus which is responsible for the well-known blight of potatoes."

In a later report by Stone (*31*) he stated: "Damp and rainy weather following a prolonged dry season caused an unusual outbreak on tomato plants, namely downy mildew, which is the same as that giving rise to the late blight of potatoes." In California, R. E. Smith (*27*), referring to the late blight of tomatoes, stated: "This trouble proved to be a common disease of another plant, which sometimes attacks the tomato, but very seldom as serious as this. It is the potato blight or mildew, well-known to every eastern potato grower. . . . The cause is a parasitic fungus, *Phytophthora infestans.*"

In describing late blight of tomato, McAlpine (*19*) stated: "It is exactly the same fungus in the tomato as that causing potato blight, and this was proved conclusively by infecting a healthy potato with the spores of the fungus from diseased tomato, and a healthy tomato was infected with the spores of Irish blight, obtained from one of the diseased potatoes grown in Beech forest."

Many similar statements can be found in the literature.

GEOGRAPHICAL DISTRIBUTION

Tomato late blight, caused by *P. infestans,* has been reported from every continent except Africa. It is found in both hemispheres and can be traced in a continuous belt around the globe. In the United States, only a few records of its appearance in the northern states are found, although it was first observed in Connecticut. It has also been reported as occurring in Maine (*33*). The disease occurs almost annually in the higher altitudes of Virginia, West Virginia, and North Carolina, (*13*). In Central America it has been reported from Mexico (*16*), Jamaica (*2*), and Porto Rico (*34*); and in South America from Uruguay (*11*). In Europe it has been reported from England (*24*), Belgium (*17*), Germany (*1*), Italy (*3*), and from practically every country on the continent. E. J. Butler (*6*) in a report of its occurrence in India wrote: "*P. infestans* was found attacking potatoes and tomatoes at Jorbat, in Assam," and he expressed the fear that this fungus was developing a race which would be able to withstand the heat of the plains. It has been repeatedly reported from Australia and New Zealand, and from the Islands of Mauritius (*29*) and Hawaii (*7*).

ECONOMIC IMPORTANCE

The economic importance of this disease is considerably minimized by the fact that it does not occur in the most important commercial tomato growing districts. On the other hand, there are certain sections in the higher altitudes of Virginia and West Virginia well adapted for tomato growing, in which it is practically impossible to grow a sufficient

supply for table use, without careful and persistent spraying. Large damage to the late crop has been reported from southern California by Smith (*27*). Again, we find a record in the Journal of the Board of Agriculture, England (*19*), where a grower lost fifty tons of a total of seventy tons, or 71 per cent of the crop. Considerable losses to the tomato crop have been reported from South Australia and New Zealand. It also has been reported as doing considerable damage to the tomato crop in Porto Rico (*34*).

THE DISEASE

The leaves, the stems, and the fruit are affected.

On the leaves and the petioles.—The infection on the foliage is so similar to the characteristic lesions of the late blight of potato that a detailed description is unnecessary. The petioles are readily attacked, and as a consequence the affected leaves often droop.

On the stem.—The disease progresses very rapidly on the tender portions of the stem, while on the older and woody parts the infection advances slowly and the lesions are much darker.

On the fruits.—The green fruits are most susceptible to the attack of the disease, although partly ripened fruit may also be infected. Most of these infections are found around the stem-end, or where two fruits come in contact with each other or with the ground. It has been demonstrated, however, that the fungus can enter through the unruptured epidermis at any point.

The first symptoms consist of irregular brown patches which at first do not extend much beyond the epidermal layer. When the conditions are more favorable, the lesions spread rapidly, and form more or less concentric zones as they advance. The infected tissues are at first firm, but they soon become soft because of the invasion of secondary organisms.

EXPERIMENTS BY OTHER INVESTIGATORS

The fact that tomato late blight rarely, if ever, appears in certain sections where potato blight is a destructive disease almost annually, has led to several investigations to determine the identity of the two diseases.

Reed (*26*) conducted experiments in Virginia, in 1911 and 1912, in which potatoes and tomatoes were planted in alternate hills. "No results were obtained in 1911; in 1912 late blight appeared on both potato and tomato on August 12." He says: "It was found possible to infect potatoes and tomatoes with the blight by taking spores from either host plant." He also states: "In making an inspection of the

diseased areas, it was found that the tomato blight was always more severe in the vicinity of potato vines. We are led to conclude, therefore, that the *Phytophthora* of the tomato is identical with that of the potato." He explains the apparent immunity of the potato crop in Virginia by the fact that a large percentage of the potatoes are planted early and consequently have made their growth before the late blight makes its appearance.

McAlpine (*21*) descirbes a similar experiment in Australia. Tomatotes and potatoes were planted in alternate rows, and his report on the experiment follows: "A row of tomatoes, containing about 150 vines, was planted alongside potatoes in the Yannathan district, the seed potatoes and the young tomato plants being planted at the same time, on December 27, 1910. About March 11 the potato tops began to show signs of disease, and in about a week they all collapsed with Irish blight. A few days after the potato plants had succumbed, the disease was noticed in the tomatoes when the fruit was forming. When I examined the plot on April 6 not a single plant had escaped, and only an occasional ripe and healthy tomato could be found, and it was evident that the tomatoes had been infected from the adjoining potatoes."

Wiltshire (*35*) conducted a series of cross inoculation experiments in 1915. Cut shoots of potatoes and tomatoes were inoculated with a spore suspension and the plants were placed under bell jars. The following are his results:

Spores from potato on potato gave 42 plants infected out of 123, or 34 per cent infection.

Spores from potato on tomato gave no infection on 143 plants used.

Spores from tomatoes on potatoes gave 4 plants infected out of 107 used, or 3 percent infection.

Spores from tomatoes on tomatoes gave 43 plants infected out of 116, or 37 per cent infection.

In another series: "Spores from tomatoes on tomato (2 plants) heavily infected."

"Spores from potatoes on tomato (2 plants) no infection."

Wiltshire concludes that these results suggest that the *Phytophthora infestans* attacking potatoes is of a different physiological strain from that attacking tomatoes.

Giddings, N. J., and Anthony Berg (*10*) conducted cross inoculation experiments with strains of the fungus isolated from tomatoes and potatoes. The results showed that the fungus would pass from one host to the other. However, the potato fungus, when inoculated on the

tomato produced only small irregular lesions on the tomato leaves. These spots were confined mostly to the lower leaves. Stem lesions did not occur in any case. The tomato strain when inoculated on tomato plants produced typical late blight infections on both leaves and stems, and the plants died down in a short time. Both the potato and the tomato strains produced typical disease lesions when inoculated on potato plants, but the tomato strain was less virulent in its attack.

Melhus, I. E. (22) apparently working with a potato strain only, summarizes the results of his experiment as follows:

"Tomato foliage is readily infected with *Phytophthora infestans* of the Irish potato, but it has not been possible to infect the fruit except through the peduncles, the calyx, or epidermis, when ruptured. Indeed when the epidermis of the fruit is intact, infection does not take place. The period of inoculation is the same for the tomato and potato, that is, six days, depending on moisture and temperature conditions. The fungus spreads and fruits more sparingly on the foliage of the tomato than on the foliage of susceptible varieties of potato and to this fact are doubtless due the numerous contradictory statements relative to the identity of species of *Phytophthora* on these two plants."

CULTURES AND EXPERIMENTAL METHODS

Numerous inoculations were made during the last five years. In the first experiment, strains of *P. infestans* isolated from potatoes were obtained from Maine, Wisconsin, and West Virginia. The tomato strains were isolated from diseased tomato fruits collected from various parts of West Virginia. Potato and tomato strains from various parts of the world have been added to this collection. The object was to collect strains for comparative study, from every country in which the fungus had been reported. This has proved to be a slow and tedious venture, although the collection is slowly increasing. We have at the present time, in addition to our native strains, potato strains from Bermuda, England, Holland, and Australia, and a tomato strain from Australia.

Methods of Collecting Material for Isolation

The following method has been found very satisfactory for transporting diseased material to the laboratory for isolation, especially where the material has to be in transit for some time. A clean potato tuber is cut into halves, the diseased leaf or stem is placed between the two halves and the pieces are firmly tied together with a string. When using parts of stems, it is best to holllow out one of the pieces of potato sufficiently to allow the halves to come firmly together after the material has been inserted. The fungus readily passes into the potato tissue

within twenty-four to forty-eight hours. At the laboratory the halves are separated, the diseased leaf or stem tissue is discarded and the tuber is put into a moist culture dish and placed in a low temperature incubator at about 15°C. If the material has been in transit for several days, especially in warm weather, *Fusarium* and other rot fungi may appear on the cut surface of the tuber. These should be removed carefully with a knife before placing the tuber in the culture dish. Tufts of *P. infestans* mycelium usually make their appearance within four or five days. The fungus is then transferred to a potato tuber prepared as follows: A healthy tuber is soaked in a 1:1,000 solution of mercuric bichloried for one hour and rinsed in distilled water. A band is peeled off in the direction of the long axis of the tuber. The tuber is then cut into equal halves with a sterile knife, and placed in a moist culture dish. Numerous stabs are made into the cut surface with the point of a sterile knife, tufts of mycelium are inserted into these stabs with a platinum needle. A pure culture can readily be obtained from these, as *P. infestans* on raw potato tissue will outgrow accompanying bacteria and fungi at temperatures of 16-18°C.

In preparing material for inoculation work the fungus was grown on potato tubers prepared as described above. The fungus covers the entire cut surface of a potato tuber in five or six days when grown at 20°C. The sporangia were then removed by directing a spray from an atomizer parallel to the cut surface of the tuber. By this method a rich suspension of sporangia comparatively free from mycelial masses can be obtained. The inoculum was applied with an atomizer, and the plants were placed in a moist chamber at around 18°C. for twenty-four hours unless otherwise stated.

Inoculation Experiments

The following series of inoculation experiments were made over a period of five years. A large number of strains were used. Some were used for one inoculation test only and then discarded, others were used for a longer period. For the sake of simplicity, the strains used in the experiments are numbered in consecutive order. The letter "P" or "T" is placed after the number to designate potato or tomato strains.

Series 1—On Tomatoes. Three sets of tomato plants, each consisting of ten plants were inoculated with strains 1P, 2P, and 3T. The first signs of infection became visible three days after the inoculation. The infected plants were then returned to the moist chamber to study the progress of the disease lesions produced by the different strains. All plants inoculated with strain 3T developed leaf, stem, and petiole infections, such as occur under natural conditions in the field. Every

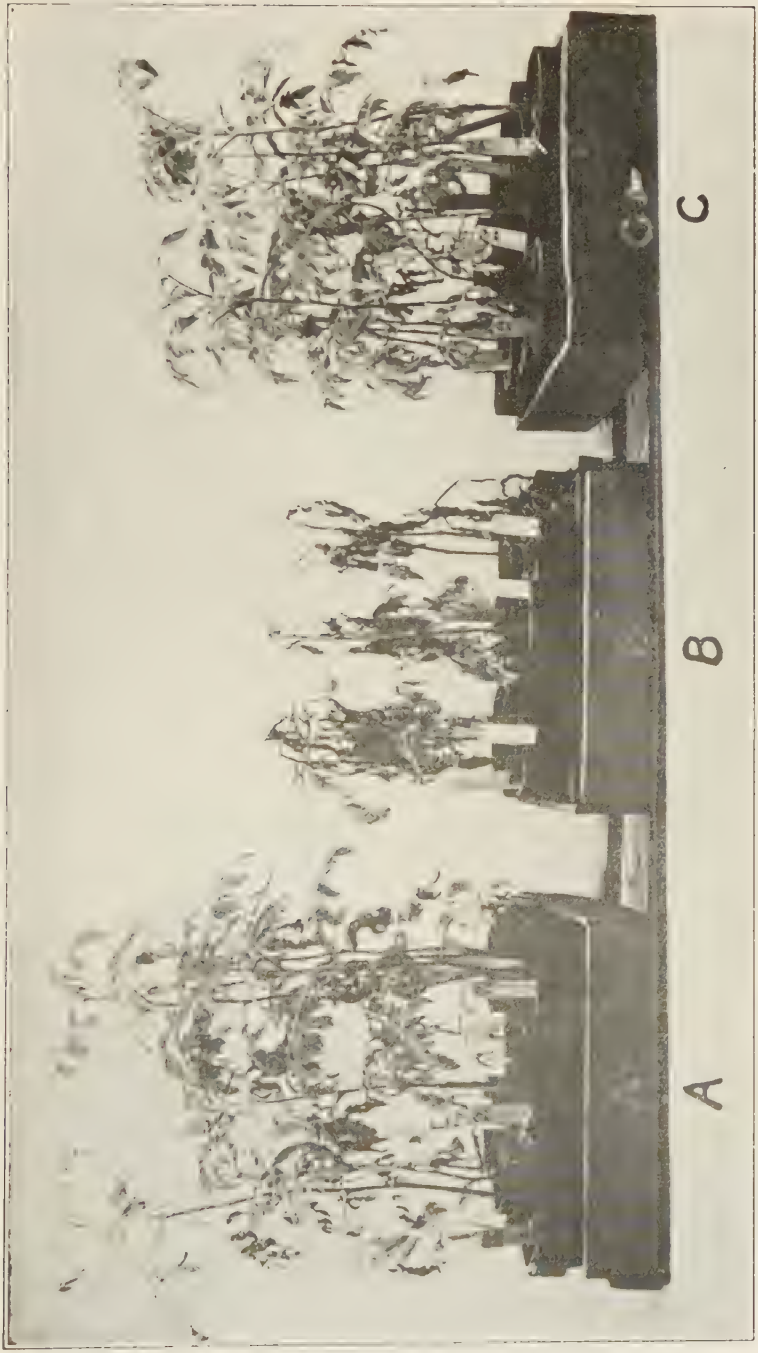


Fig. 1.—Tomato Plants Ten Days After Inoculation with Phytophthora infestans: "A" and "C" with Potato Strain, and "B" with Tomato Strain.

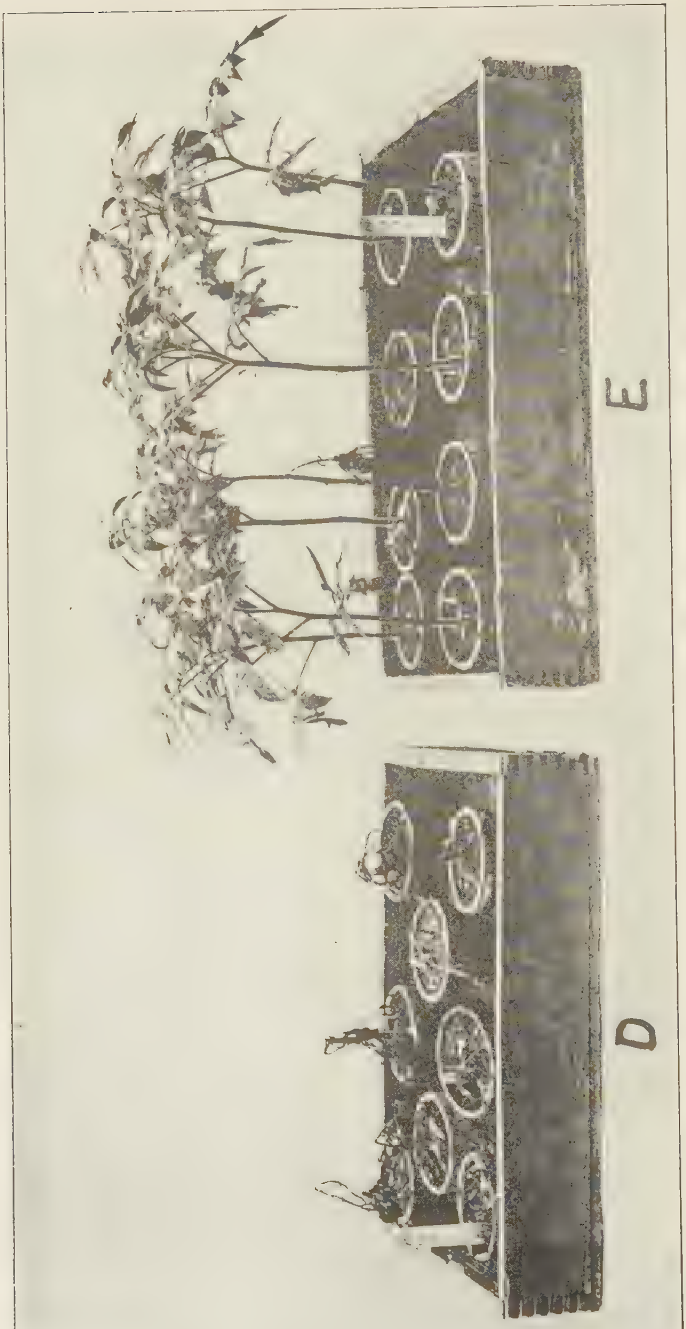


Fig. 2.—Tomato Plants Twenty-one Days After Inoculation with Phytophthora infestans: "D" Tomato Strain Showing Complete Destruction of Plants, and "E" Potato Strain Showing Loss of Lower Leaves Only.

plant succumbed to the disease in ten days (See Figure 1). The tomato plants inoculated with strains 1P and 2P, although showing a much greater number of foliage infections did not have a single petiole or stem lesion. The foliage infections were confined mostly to the older leaves and did not present the appearance of typical late blight lesions, but were blotches with irregular margins and did not exceed one-fourth of an inch in diameter (See Figure 3). They attained their maximum size four or five days after the infection became visible. The lower leaves soon dropped off and the plants fully recovered (See Figure 2).

Series 1—On Potatoes. Three sets of potato plants, each consisting of ten plants, were similarly inoculated with strains 1P, 2P, and 3T. The first signs of infection were noted in about three days after inoculation. All plants became infected. The disease produced by the tomato strain, 3T, although having the appearance of typical blight lesions, did not progress with the same vigor as that produced by the potato strains, 1P and 2P. This was especially noticeable in the case of stem infections (See Figure 4).

The sources of the strains used were as follows:
1P—Potato Strain from Morgantown, West Virginia.
2P—Potato Strain from Maine.
3T—Tomato Strain from Morgantown, West Virginia.

Series 2. This series was an exact duplication of Series 1, with identical final results. A description is, therefore, deemed unnecessary. A tomato plant inoculated with a tomato strain and a tomato plant inoculated with a potato strain were placed under moist bell jars to study the progress of the disease lesions. The lesion produced by the tomato strain progressed very rapidly and produced sporangia profusely on both surfaces of the leaf. The spots produced by the potato strain attained their maximum size within two or three days after infection first became visible, and produced sporangia only very sparingly.

Series 3. Tomato and potato plants were inoculated similarly as in Series 1 and 2, with the exception that a potato strain of *P. infestans* obtained from Wisconsin was substituted for the Maine potato strains. Late blight does not appear on tomatoes in Wisconsin and seldom, if ever, in Maine. The primary object of this inoculation experiment was to compare strains of *P. infestans* from widely separated geographical regions, especially from regions in which late blight does not appear on the tomatoes. The results were similar to those described in Series 1.

Series 4. Three tomato strains isolated from leaf, stem, and fruit respectively, were used in this inoculation experiment to test for

Fig. 3.—Tomato Leaves Showing Lesions Produced by the Potato and Tomato Strains; "A" Shows Type of Lesion Produced by Potato Strain, and "B" and "C" Typical Late Blight Lesions Produced by the Tomato Strains.

Fig. 4.—Potato Plants Fifteen Days After Inoculation with Phytophthora infestans, Showing the More Rapid Destruction of the Plants Inoculated with the Potato Strain; "A" and "C" Potato Strain, and "B" Tomato Strain.

any possible adaptation of the fungus on the various plant members. The results in the accompanying table show that such a specialization did not occur. Plants were also inoculated with a potato strain recently received from Australia, and a West Virginia potato strain for general comparison. The Australian potato strain, when inoculated on tomato, produced the same type of spots as the West Virginia potato strain, and they were similarly confined almost entirely to the lower foliage.

TABLE 1.—Inoculation of Potato Plants with Tomato and Potato Strains.

Strain Used	4T	5T	6T	7P	8P
Number of POTATO plants	10	10	10	11	12
Number of Stems	16	13	14	16	13
Number of Plants Infected	10	9	11	11	12
Stems with Stem Lesions	16	4	4	4	10

TABLE 2.—Inoculation of Tomato Plants with Potato and Tomato Strains.

Strain Used	4T	5T	6T	7P	8P
Number of TOMATO Plants	10	10	10	10	10
Number of Plants Infected	10*	10*	10*	10†	10†
Plants with Stem Lesions	10	10	10	0	0

(*) Typical Late Blight lesions on foliage and stems.
(†) Numerous small lesions on lower leaves.

The sources of the strains used in this series were as follows:

4T—Tomato strain isolated from diseased fruit, Morgantown, West Virginia.

5T—Tomato strain isolated from diseased leaf, Morgantown, West Virginia.

6T—Tomato strain isolated from diseased stem, Morgantown, West Virginia.

7P—Potato strain, tuber isolation from Australia.

8P—Potato strain, leaf isolation from Morgantown, West Virginia.

Series 5. The object of this series was to test the probable effect of different climatic conditions brought about by variations in altitude.

TABLE 3.—Inoculations with Tomato and Potato Strains from Different Altitudes.

Strain Used	9T	10T	11T	12P
Number of TOMATO plants	8	8	8	8
Number of Plants Infected	8*	8*	8*	8†
Plants with Stem Lesions	8	8	8	0

(*) Typical late blight lesions on stems and foliage.
(†) Numerous small spots on lower leaves.

Fig. 5.—Tomato Plants Fifteen Days After Inoculation with Tomato and Potato Strains of Phytophthora infestans. "A," Tomato Strain from West Virginia. "B," Potato Strain from West Virginia. "C," Tomato Strain from Australia. "D," Potato Strain from Australia.

The sources of the strains and the altitudes were as follows:

9T—Tomato strain isolated from Davis, West Virginia, altitude 3,300 feet.

10T—Tomato strain isolated from Montrose, West Virginia, altitude 1,600 feet.

11T—Tomato strain isolated from Morgantown, West Virginia, altitude 1,000 feet.

12P—Potato strain isolated from Morgantown, West Virginia, altitude 1,000 feet.

The climate of Davis, West Virginia, is cool and the seasons are **not unlike** those of the northern states where late blight of potato occurs almost every year, but tomato late blight has never been known to occur. Destructive outbreaks of late blight of tomatoes have been repeatedly observed at high altitudes. It would, therefore, seem that some factors aside from climatic conditions are responsible for the absence of tomato late blight in some of our northern states. It may be possible that the tomato fungus living on a plant that dies completely in the autumn is dependent on hibernation in the soil, whereas the potato strain is carried over, at least in part, through diseased tubers. It is therefore quite probable that the tomato fungus cannot survive the cold winters of the north, while in the regions of milder winters, it may live over in the soil at lower altitudes and then gradually spread to the adjacent higher altitudes as the season advances. The results of this inoculation experiment would tend to indicate that other factors than climatic conditions are involved in this peculiar stiuation. Potato strains obtained from these altitudes did not produce typical late blight infections when inoculated on tomato plants.

Series 6. A third host plant of *P. infestans, Solanum aviculare,* was introduced into this series. It was hoped that by this means a further differentiation of the two strains might be obtained. *Solanum aviculare* is an Australian plant and has been reported as being very susceptible to infection by *P. infestans.*

The plants were interplanted with tomatoes and potatoes in the pathological garden where the tomato and potato plants have annually suffered from the natural infections of the fungus. The potato and tomato plants became heavily infected during August and September. The "kangaroo apples" (*Solanum aviculare*) also became infected, however, to a much less degree than either of the other two host plants. Isolations were made from three of the infected plants during the season. The cultures were marked "?" pending a definite determination of strain by artificial inoculations. The results of the inoculation shown in

Table 4 indicate that *Solanum aviculare* is susceptible to infection by both strains of the fungus under natural conditions.

TABLE 4.—Inoculations with Strains Isolated from Solanum aviculare and Tomato Fruit.

Strain Used	13?*	14?**	15?†	16T ?‡
Number of TOMATO Plants	12	12	12	12
Number of Plants Infected	12	12	12	12
Plants with Stem Lesions	0	12	0	0

*Isolated from *Solanum aviculare* proved to be a potato strain.
**Isolated from *Solanum aviculare* proved to be a tomato strain.
†Isolated from *Solanum aviculare* proved to be a potato strain.
‡Isolated from tomato fruit proved to be a potato strain.

Both tomatoes and potatoes were badly blighted at the time isolations were made. Strain 16T was isolated from a disease lesion of a tomato fruit.

Tomato fruits infected with the potato strain are occasionally found where tomato plants are intermingled with heavily infected potato plants. It is very probable that such infection takes place through a rupture in the epidermis of the tomato fruit. This may in part account for the reports of sporadic occurrence of tomato blight in certain regions.

Series 7.—One set of thirty-five plants of kangaroo apples (*Solanum aviculare*) were inoculated with potato strain 12P, and a similar lot of thirty-five plants were inoculated with tomato strain 9T. The first signs of infection were visible in four days. All plants were heavily infected, both on the foliage and on the young shoots. There appeared to be no difference in the susceptibility of *Solanum aviculare* to either strain in artificial inoculations.

Series 8.—To determine the time required for the tomato and potato strain to infect the tissues of the potato plants a series of inoculations were made in which the plants were removed from the moist chamber at definite intervals. After removal from the moist chamber the plants were immediately taken to a warm room and the excess moisture on the foliage was dried off quickly by means of an electric fan.

TABLE 5.—Time Required for Penetration and Infection On Potato Plants.

Items Considered	Time in Moist Chamber After Inoculation					
	3½ Hours		6 Hours		24 Hours	
Strains Used	17T*	18P†	17T*	18P†	17T*	18P†
Number POTATO Plants	16	16	16	16	16	16
Number Plants Infected	0	2	0	11	16	16
Stems with Stem Lesions	0	2	0	5	11	16

*Tomato Strain from West Virginia.
†Potato Strain from West Virginia.

Fig. 6.—Tomato Plant Ten Days After Inoculation with Tomato Strain, Showing Stem, Leaf, and Petiole Infection.

From these data, it appears that it takes a longer period of time for the tomato strain to penetrate the potato tissue and produce infection than it does for the potato strain.

Series 9.—This inoculation is a duplicate of Series No. 8 with the exception that a potato strain from Maine was substituted for the West Virginia strain. The results are practically identical.

TABLE 6.—Time Required for Penetration and Infection on Potato Plants.

Items Considered	Time in Moist Chamber After Inoculation					
	3½ Hours		5¾ Hours		8 Hours	
Strain Number	2P*	17T†	2P*	17T†	2P*	17T†
Number POTATO Plants	12	12	12	12	12	12
Total Number of Stems	27	24	27	19	27	22
Number of Plants Infected	3	0	12	1	12	4
Number of Stems Infected	3	0	22	1	26	4

*Potato strain from Maine.
†Tomato strain from West Virginia.

TABLE 7.—Time Required for Penetration and Infection on Tomato Plants.

Items Considered	Time in Moist Chamber After Inoculation							
	3½ Hours		5½ Hours		9 Hours		24 Hours	
Strain Number	T	P	T	P	T	P	T	P
Number of TOMATO Plants	6	6	6	6	6	6	6	6
Number of Plants Infected	0	0	3	0	5	2	6	6
Plants with Stem Lesions	0	0	3	0	4	0	6	0

Series 10.—In this series, tomato plants were inoculated with the potato strain of *P. infestans* while potato plants were inoculated with a tomato strain of *P. infestans.* The plants were removed from the moist chamber at various intervals, and the excess moisture dried off by means of a fan.

TABLE 8.—Time Required for Penetration and Infection on Tomato Plants.

Items Considered	Time in Moist Chamber After Inoculation							
	3½ Hours		5½ Hours		9 Hours		24 Hours	
Strain number	17T	2P	17T	2P	17T	2P	17T	2P
Number TOMATO Plants	8	8	8	8	8	8	8	8
Number of Plants Infected	0	0	1	0	5	8*	8	8†
Plants with Stem Lesions	0	0	1	0	5	0	8	0

*Few small spots on lower leaves.
†Numerous small spots on lower leaves.

It should be noted that in the nine hour interval, the number of tomato plants infected by the potato strain was greater than the number of plants infected by the tomato strain. However, the plants infected by the potato strain contained only a few small lesions on the very lower leaves.

Heavy infection on the upper foliage which is much more resistant to the potato strain, appeared only on the plants that were left in the chamber for twenty-four hours. In certain inoculation experiments for demonstration purposes where temperature conditions were too high for optimum germination of *P. infestans* spores, the potato strain sometimes infected only a few of the lower leaves or failed entirely and vice versa.

It is questionable whether the potato strain will infect tomato foliage in nature. By close observation in fields where the two plants were interplanted and the potato foliage heavily infected, no infections could be noted on the tomato foliage. Fields of tomatoes heavily infected were also observed in which intermingled potato plants were growing free from blight. It would appear, therefore, that the two strains are rather closely host adapted, and that a transfer from one host to the other takes place only under the most favorable conditions.

TABLE 9.—Time Required for Penetration and Infection On Potato Plants.

Items Considered	Time in Moist Chamber After Inoculation							
	3¼ Hours		5½ Hours		9 Hours		24 Hours	
Strain Number	17T*	2P†	17T*	2P†	17T*	2P†	17T*	2P†
Number POTATO Plants (in pots)	14	14	14	14	14	14	14	14
Number of Stems	24	38	32	33	36	48	32	48
Number of Stems Infected	0	13	8	28	6	48	18	48
Number Lesions on Body of Stem	0	8	0	18	9	46	2	48

*Tomato strain from West Virginia.
†Potato strain from Maine.

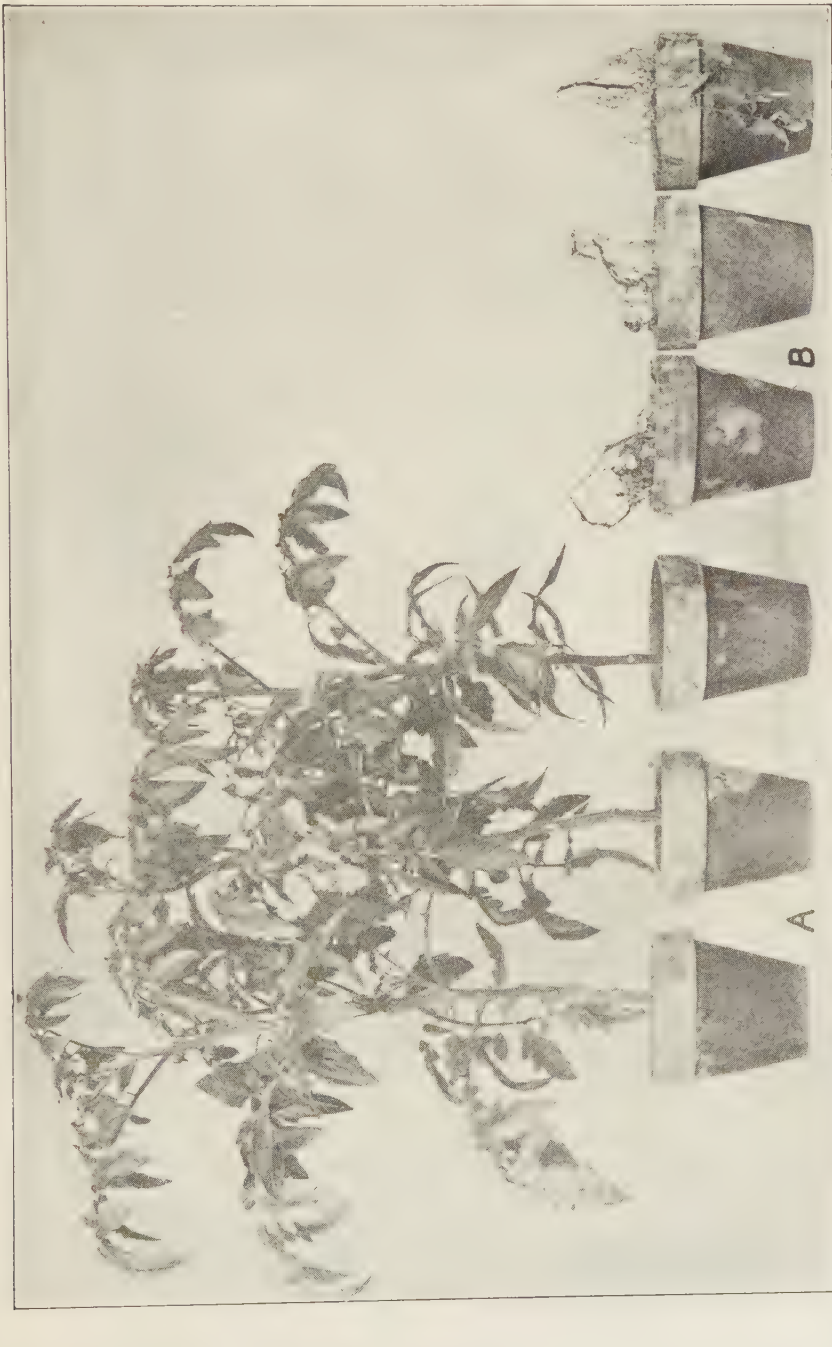


Fig. 7.—Tomato Plants Three Weeks After Inoculation with Phytophthora infestans; "A" Plants Inoculated with the Potato Strain Showing Defoliation of Lower Leaves Only and Complete Recovery of Plants, and "B" Plants Inoculated with the Tomato Strain.

From the foregoing results it appears to take a longer interval of time for the potato strain to penetrate the tomato tissue and produce infection than it required for the tomato strain. On the other hand, the results given in Tables 5, 6, and 8 indicate that it takes a longer period of time for the tomato strain to penetrate the tissues of the potato plant and produce infection than is required by the tomato strain. The number of potato stem infections produced by the tomato strain was appreciably less and the diseased lesions did not progress as rapidly as those produced by the potato strain. This has manifested itself in several inoculation experiments.

Series 11.—The object of this experiment was to test the degree of stability of the tomato and the potato strains of *P. infestans*. A tomato strain, 17T, isolated from a diseased tomato fruit collected at Davis, West Virginia, was grown on potato tubers for twelve months. It was transferred forty-nine times during this period. A potato strain, 18P, isolated from a diseased potato leaf, gathered in our pathological garden at Morgantown was carried for four months on tomato plugs cut from green tomato fruits. During this period it was transferred fifteen times. It was then transferred to young tomato stems sterilized by soaking in a solution of 1:1000 bichloride of mercury, rinsed in distilled water, then dipped into alcohol and flamed. The stems were then placed in sterile test tubes with a moist cotton plug in the bottom. The fungus was transferred into a slit into the side of the stem, as the potato strain will not grow on tomato stems unless inserted through the epidermis. After three transfers at intervals of two weeks each, the fungus growth became so weak that it had to be transferred back to the tomato plugs, on which it was grown six weeks longer, being transferred five times. The fungus was then transferred to halves of potato tubers to secure better growth and produce a sufficient quantity of sporangia to inoculate a number of plants.

TABLE 10.—Inoculation of Tomato Plants with Tomato and Potato Strains.

Strain Numbers	17T	18P
Number TOMATO Plants	43	40
Number Plants Infected	43†	40*
Plants with Stem Lesions	43	0

*Small lesions, mostly on lower leaves.
†Typical late blight lesions on leaves and stems.

TABLE 11.—Inoculation of Potato Plants with Tomato and Potato Strains.

Strain Numbers	17T*	18P†
Number POTATO Plants	12	12
Total Number of Stems	22	26
Number of Plants Infected	10	12
Stems with Stem Lesions	16	26

*Tomato strain from Davis, West Virginia.
†Potato strain from Morgantown, West Virginia.

The fact that a tomato strain could be grown for about one year on potato tissue with constant transferring on the average of once a week, and that a potato strain could be grown on tomato tissues for seven months and retain its original virulence, indicates that these strains possess considerable stability.

Series 12.—In this series we have a comparison between a tomato and a potato strain of the fungus, obtained from Australia, with a tomato and a potato strain isolated at Morgantown, West Virginia. It is remarkable to note that the same biological differentiation prevails in Australia as in America.

TABLE 12.—Comparison of Tomato Strains from Australia and from West Virginia on Tomato Plants.

Strain Numbers	11T	18P	19T	7P
Number TOMATO Plants	12	12	12	12
Number Plants Infected	12†	12*	12†	12*
Plants with Stem Lesions	12	0	12	0

*Small lesions, mostly on lower leaves.
†Typical late blight lesions on leaves and stems.

TABLE 13.—Comparison of West Virginia Potato and Tomato Strains with Potato and Tomato Strains from Australia.

Strain Number	11T*	18P**	19T†	7P†
Number POTATO Plants	14	13	15	12
Number of Stems	44	32	46	37
Number of Plants Infected	10	13	16	12
Number of Stems Infected	16	32	20	37

*Tomato strain from Morgantown, West Virginia.
**Potato strain from Morgantown, West Virginia.
†Tomato strain from Australia.
‡Potato strain from Australia.

The Australian potato strain produced numerous small spots, mostly confined to the lower leaves, similar to the infection produced by the American potato strain. The Australian tomato strain produced typical

late blight lesions on both leaves and stems of the tomato plants. These stem lesions, however, did not progress as rapidly as the one produced by American strains. This was noted in repeated inoculation tests.

Series 13.—In this inoculation experiment we have a number of strains from widely separated continents for comparative study.

TABLE 14.—Inoculation of Potato Plants with Potato and Tomato Strains from Five Different Countries.

Strain Number	20P	21P	22P	7P	19T	23P	24T
Number POTATO Plants	6	6	6	6	6	6	6
Hours Required for Infection to Appear	80	80	80	90	90	80	72
Number of Plants Infected	6	6	6	4	6	6	6

TABLE 15.—Inoculation of Tomato Plants with Potato and Tomato Strains from Five Different Countries.

Strain Number	20P	21P	22P	7P	19T	23P	24T
Number TOMATO Plants	6	6	6	6	6	6	6
Hours Required for Infection to Appear	60	60	60	64	70	60	94
Number of Plants Infected	6	6	6	6	6	6	6
Plants with Stem Lesions	0	0	0	0	6	0	6

The sources of the strains used in this series were as follows:

20 P—Potato strain from Bermuda.
21 P—Potato strain from Holland.
22 P—Potato strain from England.
7 P—Potato strain from Australia.
19 T—Tomato strain from Australia.
23 P—Potato strain from West Virginia.
24 T—Tomato strain from West Virginia.

It should be noted that a potato strain of *P. infestans* did not produce a stem lesion or a typical late blight lesion on the foliage of the tomato plants in any instance. In all cases, however, numerous small lesions were produced on the lower foliage with a gradual diminution in size and number towards the younger foliage. On the other hand, typical late blight lesions were obtained on both foliage and stems of all tomato plants inoculated with the American and Australian tomato strains. An accurate account was kept of the period of incubation required for the various strains. It should be noted that the period of incubation for the potato strain on tomato is shorter than that of the tomato strain on the same host plant, although as was shown in Series Nos. 8 and 9, it takes a longer period of time for the potato strain to penetrate the tomato tissue and produce infection than is required for the tomato strain.

Series 14.—To study further the relative pathogenicity of the tomato and the potato strains on potato, inoculations were made upon potato plants of the variety "Success" which has a rather resistant foliage.

TABLE 16.—Inoculation of Resistant Potato Plants with Tomato and Potato Strains.

Strain Number	11T*	18P†
Number POTATO Plants	12	12
Total Number of Stems	21	18
Number of Stems Infected	1	12
Stems with Stem Lesions	0	9

*Tomato strain from Morgantown, West Virginia.
†Potato strain from Morgantown, West Virginia.

The fact that only one plant was infected by the tomato strain again indicates that this strain does not possess the same virulence on the potato plant as that possessed by the potato strain.

Series 15.—Green tomato fruits about half to two-thirds grown were inoculated by placing droplets of water containing a rich suspension of sporangia on the blossom ends of the fruits. Great care was taken to select fruits free from blemishes or bruises. The tomatoes were separated into two similar lots. One lot was inoculated with a potato strain and the other with a tomato strain. A plate from each lot was removed from the inoculation chamber at intervals as shown in Tables 17 and 18. The droplets containing the inoculum were removed by means of filter paper immediately after taking the fruits from the moist chamber.

TABLE 17.—Inoculation of Tomato Fruits with Potato and Tomato Strains and Infection with Different Lengths of Time in Inoculation Chamber.

Items Considered	Time in Moist Chamber After Inoculation									
	3½ Hours		5 Hours		8 Hours		10 Hours		24 Hours	
Strain Number	26P*	27T†	26P*	27T†	26P*	27T†	26P*	27T†	26P*	27T†
Number TOMATO Fruits	8	8	8	8	8	8	8	8	8	8
Number of Fruits Infected	0	0	0	3	0	4	0	6	0	8

*Potato strain from Parsons, West Virginia.
†Tomato strain from Parsons, West Virginia.

TABLE 18.—Inoculation of Tomato Fruits with Potato and Tomato Strains and Infection with Different Lengths of Time in Inoculation Chamber.

Items Considered	Time in Moist Chamber After Inoculation									
	2½ Hours		3½ Hours		6 Hours		10 Hours		24 Hours	
Strain Number	28P*	27T†	28P*	27T†	28P*	27T†	28P*	27T†	28P*	27T†
Number TOMATO Fruits	10	10	10	10	10	10	10	10	10	10
Number of Fruits Infected	0	0	0	1	0	5	0	7	0	10

*Potato strain from Bermuda.
†Tomato strain from West Virginia.

Out of the 90 fruits inoculated with the potato strain not a single infection was noted. While the tomato strain in one case produced infection within a period of three and one-half hours after inoculation. The first signs of infection were noted five days after inoculation.

In another experiment sound, green tomato fruits were divided into three lots of twenty each. One lot of twenty tomatoes was inoculated on the uninjured surface with the tomato strain of *P. infestans*; another lot of twenty tomatoes was inoculated on the uninjured surface with the potato strain; and the third lot of twenty tomatoes was first wounded by means of numerous light pin pricks, and then similarly inoculated at the points of injury, with the potato strain. The method of inoculation was the same as described for Series No. 15. All fruits were allowed to remain in the inoculation chamber for twenty-four hours. In four and one-half days the first signs of infection were noted on the wounded fruits inoculated with the potato strain. All fruits inoculated with the tomato strain showed signs of infection five days after inoculation. None of the sound fruits inoculated with the potato strain became infected. Tomato fruits do not have stomata. It is evident, therefore, that the potato strain is not capable of penetrating the cutinized epidermis of the tomato fruit. However, when the epidermis is ruptured, infection takes place. The diseased areas thus produced by potato strains of *P. infestans* enlarge at a much slower rate than those produced by a tomato strain. The resistance of tomato fruit to the invasion of the potato *Phytophthora* is to be explained not only by the inability of the fungus to gain entrance, but also by the presence of some resistant principle inherent in the tissues of the tomato.

FIELD OBSERVATIONS

The development of potato and tomato late blight in nature has been under observation by the writer for more than ten years. During this period, it has always been noted that the late blight of tomato makes its

appearance from four to six weeks after the potato late blight. In instances where the early development of the blight was kept under close observation, the first signs of tomato blight were found on the plants adjacent to potato plants that were heavily infected with *P. infestans.*

In plots where tomatoes and potatoes were planted in alternate rows the potato plants sometimes became infected and completely died before any signs of infection could be noted on the tomato plants. It may be of interest to quote a passage from Dr. Brittlebank's* letter to Dr. Giddings in this connection: "Prior to the advent of *P. infestans* in our potato crop there was no record of tomato plants being affected, and we did not observe a case until the year following the first epidemic of late blight."

STUDIES OF THE FUNGUS IN CULTURE

In determining the H-ion concentration of the extract of tomato fruits, leaves, and stems as well as that from potato tubers, stems, and leaves, it was found that the tomato extracts have a higher acidity than the potato extracts. This led to the belief that the difference in strains may perhaps be due to a higher acid tolerance of the tomato strain. Accordingly, a series of oatmeal agars with varying concentrations of citric, lactic, and malic acids was prepared. The results obtained were not uniform enough to warrant any definite conclusions. It was found, however, that the tomato as well as the potato strain would grow on a medium of much higher acid content than that of the tomato fruit or stem extract.

Strains of *P. infestans* from tomato when transferred to raw potato tubers, will in most cases, grow as luxuriently as the fungus from potato on the same medium. It has been repeatedly observed, however, that the growth of the tomato strain is inhibited to a much greater extent than that of the potato strain when grown on tubers of blight resistant varieties, or tubers that have been in storage for a considerable time.

The potato strain can be cultured on blocks cut from green tomato fruits but the growth produced is less vigorous than that produced by the tomato strain when grown on raw potato blocks. The potato strain has a tendency to produce deformed and undersized sporangia when grown on tomato tissue.

The facts that the tomato strain can readily be transferred to potato tubers and the potato strain can be induced to infect tomato fruits when inoculated through the epidermis led several investigators to believe that there was no biological specialization and that the fungus on potato readily passed over to the tomato plants in nature.

*The writer wishes to express his indebtedness to Dr. C. Brittlebank, of Melbourne, Australia, for his prompt and splendid cooperation in furnishing us cultures of *P. infestans*, seeds of *Solanum aviculare*, and valuable information on the behavior of *P. infestans* in Australia.

Considerable divergence has been observed in the behavior of both the potato and the tomato strain in culture. Some cultures will go into a vegetative stage after being cultured for a short period of time, and fail to produce sporangia when transferred to raw potato blocks. Other cultures will consistently produce sporangia in profusion even after years of culture on artificial media. Sometimes a culture will lapse into a quiescent state for a period of time, producing only sparse growth, and then suddenly regain vigor and produce a very profuse growth.

Oospores.—Oospore-like bodies were first observed in 1919 in potato and tomato strains obtained from Australia. The fungus was cultured on raw potato tubers at that time. These bodies were produced in quantities and in several instances approached maturity although the majority disintegrated in a short time. Bodies of similar nature have been observed frequently since in other cultures. These bodies are formed in the aerial mycelial weft, but never in the potato tissue. The writer is inclined to believe that these bodies are abortive oospores which do not function in the life cycle of the fungus.

Mature oospores with well defined amphigenous antheridia have been found, occasionally in cultures grown on Quaker Oat media. Oospores do not seem to be produced with any degree of regularity. Cultures that produce oospores at one time may fail to do so under identical conditions at another time. Well defined oospores were never found in American cultures. The cultures in which oospores were produced were obtained from Australia, Holland, and England. The cultures that produced oospores were very vigorous growers and produced very few sporangia.

SUMMARY

1.—The *P. infestans* which produces late blight of tomato differs biologically from the form which produces potato blight. This has manifested itself in a large number of inoculation experiments.

Foreign strains of the fungus studied behave like American strains in this respect.

2.—The potato *P. infestans* will infect the tomato fruit and leaves under artificial conditions. The older leaves are most susceptible. On such leaves numerous small lesions are produced in which the fungus soon dies out and the plants fully recuperate. The tomato fruits could not be infected with this strain, unless by first rupturing the epidermis.

3.—The period of incubation for the potato strain, when inoculated on tomato plants, is shorter than that of the tomato strain on the same host and vice versa, in the forms studied.

4.—In all cases observed under natural conditions, potato late blight

appeared earlier in the season than the tomato late blight and wherever tomato late blight was found potato late blight also occurred in close proximity.

BIBLIOGRAPHY

(1) APPEL, O.
1906. NEURE UNTERSUCHUNGEN UBER KARTOFFEL—UND TOMATEN—ERKRANKUNG. Sond. Jahrber. d. ver. d. Vertr. Agnew. Bot. III, 1906.

(2) ASHBY, S. F.
1917. ANNUAL REPORT OF THE MICROBIOLOGIST. 1916-1917. Ann. Rept. Dept Agr. Jamaica, 1917: 26-28.

(3) BRIOSI, G.
1899. A REVIEW OF FUNGOUS DISEASES OBSERVED DURING 1897. Attic Inst. Bot. Univ. Pavia, 2 ser. 5: 327-352.

(4) BRITTLEBANK, C. C.
1919. TOMATO DISEASES. Jour. Dept. Agr. Victoria 17: 231-235 and 498-500.

(5) ----------------------
1920. TOMATO DISEASES. Jour. Dept Agr. Victoria 18: 413-416.

(6) BUTLER, E. J.
1912. REPORT OF THE IMPERIAL MYCOLOGIST. Rept. Agr. Inst. and Col. Pusa (India) 1911-1912: 54-64.

(7) CARPENTER, C. W.
1917. REPORT OF THE DIVISION OF PLANT PATHOLOGY. Hawaii Agr. Exp. Sta. Rept. 1917: 33-42.

(8) DARNELL-SMITH, G. P.
1921. DISEASES OF TOMATO SEEDLINGS. Agr. Gaz. N. S. Wales 32: 577.

(9) FINARDI, E.
1912. VEGETABLE PARASITES OF TOMATO. Avven. Agr. 20: 290-292.

(10) GIDDINGS, N. J. and BERG, ANTHONY
1920. A COMPARISON OF THE LATE BLIGHT OF TOMATO AND POTATO. Phytopahtology 9: 209-210. 1 plate.

(11) GIRADI, J.
1917. TOMATO DISEASES. Rev. Min. Indus. Uruguay 5: 423-428.

(12) HERBERT, D. A.
1919. PATHOLOGICAL REPORT—WESTERN AUSTRALIA. Dept. Agr. and Indus. West Aust. Ann. Rept. 1919: 29.

(13) JEHLE, R. A., GOODMAN, J. W., and LINDLEY, J. W.
1919. CONTROL OF LATE BLIGHT OF TOMATOES IN THE BLUE RIDGE MOUNTAINS. Bul. N. C. Dept. Agr. 40: 3-16.

(14) JOHNSTON, T. HARVEY
1910. IRISH BLIGHT IN TOMATOES. Agr. Gaz. N. S. Wales 21: 563-566.

(15) KERN, F. C. and ORTON, C. R.
1916. PHYTOPHTHORA INFESTANS ON TOMATOES. Phytopathology 6: 284-287.

(16) MADARIAGA, A. and VILLARREAL, R.
1916. CONTROL OF PHYTOPHTHORA INFESTANS IN THE FLOATING GARDENS OF XOCHINNILCO. Bol. Dir. Agr. (Mex.) 2: 55-57.

(17) MARCHAL, E.
1901. IN BELGEN IM JAHRE 1901. BEOBACHTETE PILZ PARASITARE. Rapports sur les Maladies crytogamiques etudiets au Labaratoire de Botanique de l' Institut agricole de Gembloux 1901: 3-4.

(18) MANN, E. A.
1919. REPORT OF PLANT DISEASES. West Aust. Govt. Ann. Rept. 1919: 8.

(19) McALPINE, D.
1910-a. THE LATE BLIGHT IN TOMATOES. Jour. Dept. Agr. Victoria 8: 48-49.

(20) ------------------------
1910-b. SOME POINTS OF PRACTICAL IMPORTANCE IN CONNECTION WITH THE LIFE-HISTORY STAGES OF PHYTOPHTHORA INFESTANS (MONT) DeBARRY. Annales Mycologici 8: 156-166.

(21) ------------------------
1911. TOMATOES AND IRISH BLIGHT. Jour. Dept. Agr. Victoria 9: 379-382.

(22) MELHUS, I. E.
1916. INFECTION AND RESISTANCE STUDIES OF PHYTOPTHORA INFESTANS ON THE TOMATOES. Abs. in Phytopathology 6: 107.

(23) PAYEN, M.
1848. ON THE VEGETATION OF BOTRYTIS INFESTANS IN THE INTERIOR OF THE TOMATO. Gard. Chron. and Agr. Gaz. 1848: 51-52.

(24) PLOWRIGHT, CHAS. B.
1881. ON THE FUNGOID DISEASES OF THE TOMATO. Gard. Chron. 16: 620-621.

(25) ------------------------
1884. TOMATO DISEASES. Gard. Chron. 22: 628.

(26) REED, H. S.
1912. DOES PHYTOPHTHORA INFESTANS CAUSE TOMATO BLIGHT? Phytopathology 2: 250-252.

(27) SMITH, RALPH E.
1906. TOMATO DISEASES IN CALIFORNIA. Cal. Agr. Exp. Sta. Bul. 175: 16.

(28) SMITH, W. E.
1881. DISEASES OF TOMATOES. Gard. Chron. 16: 346.

(29) STOCKDALE, F. A.
1915. REPORT ON PLANT DISEASE. (IN SUMMARY OF INVESTIGATIONS MADE DURING THE PERIOD JANUARY 1 TO JUNE 30, 1915). Mauritius Dept. Agr. 1915: 1-2.

(30) STONE, G. E.
1911. DISEASES OF TOMATOES. Mass. Agr. Exp. Sta. Bul. 138: 13.

(31) -------------- and MONAHAN, N. F.
1906. ANNUAL REPORT, 1906. Mass. (Hatch) Agr. Exp. Sta. Ann. Rept. 1906; 115.

(32) STURGIS, WM. C.
1893. COMMON FUNGOUS DISEASES AND THEIR TREATMENT. Conn. (New Haven) Agr. Exp. Sta. Bul. 115: 17.

(33) THAXTER, ROLAND
1890. REPORT OF THE MYCOLOGIST. Conn. (New Haven) Agr. Exp. Sta. Rept. 1890: 95.

(34) THOMAS, H. E.
1917. REPORT OF THE PLANT PATHOLOGIST. Porto Rico Agr. Exp. Sta. Rept. 1917: 28-30.

(35) WILTSHIRE, S. P.
1915. A NOTE ON PHYTOPHTHORA INFESTANS OCCURING ON TOMATOES. Univ. Bristol, An. Rept. Agr. and Hort. Res. Sta. 1915: 92-93.

(36) ZACHAREWIZ, ED.
1889. TRAITMENT DE LA MALADIE DES POMMES DE TERRA, DES TOMATOES, ET DES MELONS PAR LES SELS DE CUIVRE. Le Progres Agricole et Viticole 14 Julliet, 1889.

Bulletin 207

July, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

A Balanced and An Unbalanced Ration Fed Prior to the Hatching Season As Affecting the Hatchability of Eggs and the Vigor of the Progeny

(Technical)

By
HORACE ATWOOD

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. . . . . President of the University
HENRY G. KNIGHT, Ph. D. . . . . Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S., Agr. . . . . Agricultural Editor
JOHN C. JOHNSTON . . . . Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
E. P. Deatrick, Ph. D. — Associate Soil Technologist
T. E. Odland, Ph. D. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist
D. R. Dodd, M. S. — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
J. H. Longwell, M. S. — Assistant Animal Husbandman
J. H. Rietz, D. V. M. — Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
L. P. Hansen, Ph. D. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
Paul Daughenbaugh — Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
G. Malcolm Trout, M. S. — Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
L. E. Dills, B. S.** — Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, Jr., M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M. — Home Economist
Hazel C. Cameron, M. S. — Research Specialist in Foods
Nell Nesbitt, A. M. — Research Specialist in Home Mana't

HORTICULTURE

H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
H. P. Sevy, M. S. Agr. — Assistant in Horticulture
M. B. Hoffman, M. S. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman
E. T. Wightman, M. S. Agr. — Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D. — Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D. — Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

A BALANCED AND AN UNBALANCED RATION FED PRIOR TO THE HATCHING SEASON AS AFFECTING THE HATCHABILITY OF EGGS AND THE VIGOR OF THE PROGENY

The period during which hens can produce eggs profitably is usually limited to the first two years of their lives. This makes it necessary, in practice, to replace about one-half of the laying flock with pullets each fall, and as this requires raising at least twice as many chickens as there are birds in the laying flock any information which sheds light on the factors which affect the hatchability of eggs or the vigor of chickens is of practical importance to the poultryman.

Does heavy laying during the winter and early spring months measurably decrease the hatchability of the eggs, or the vigor of the progeny produced later in the season? If this should be the case it would be necessary, for best results, to feed and manage the breeding flock so that few eggs would be produced during the period immediately prior to the hatching season.

The experiment herein reported was planned to give the information desired.

General Plan of the Experiment

The experiment was begun November 1, 1923, and was concluded September 19, 1925. The fowls used were Single Comb White Leghorns of the strain developed at the West Virginia Agricultural Experiment Station. The birds were hatched May 9, 1923, and they were raised under practically free range conditions.

Six pens of fowls were employed, each consisting of 16 female birds. They were housed in separate colony houses, numbered 4 to 9, and trapped. During the winter of 1923-24 the fowls in houses 5, 8, and 9, hereafter designated as Lot 1, were fed for egg production, while the other fowls were fed principally upon whole grain so that few eggs were laid. During the succeeding winter, however, the rations were reversed, the fowls in Lot 2 being fed for eggs and those in Lot 1 receiving the whole grain ration.

In the spring of 1924 and also in 1925 eggs laid by these fowls were incubated and a record was kept of the fertility and hatchability of the eggs and the mortality and rate of growth of the offspring.

RATIONS USED

The mixture of whole grain consisted of two parts by weight of yellow corn, two parts of wheat, and one part of oats. The mash was composed of two parts of yellow corn meal, and one part each of wheat bran, wheat middlings, and meat scrap. The mash was self-fed in hoppers and the whole grain in straw litter. The fowls fed for egg

production also received a moderate allowance of semi-solid buttermilk. The fowls fed for low egg production were fed liberally upon the whole grain mixture until a short time before eggs were saved for hatching. Then these fowls, also, received mash and semi-solid buttermilk.

WEIGHING THE FOWLS

Each bird was weighed at the beginning of each calendar month, beginning November 1, 1923. This was done at night soon after the birds had assembled on the perches.

Table 1 shows the number of pounds of feed consumed by each lot of 48 fowls per month, the total number of eggs laid per month, and the average weight of the birds.

TABLE 1.—Feed Consumed, Eggs Laid, and Average Weight of Birds by Months for Lots 1 and 2 During the First Year.

Lot 1. Pens 5, 8, and 9, Fed for High Egg Production					
Months	Pounds Whole Grain	Pounds Mash	Pounds Semi-Solid Buttermilk	Number of Eggs Laid	Average weight of Birds in Pounds
1923 November	181	83	45	408	3.22
December	175	122	46	395	3.49
1924 January	168	114	46	173	3.57
February	158	114	43	529	3.67
March	154	165	48	1012	3.68
April	167	183	46	1109	3.64
May	173	181	46	1084	3.63
June	172	150	38	964	3.54
July	164	171	35	877	3.61
August	132	158	35	632	3.37
September	119	141	33	301	3.37
October	131	117	35	128	3.41
Total	1894	1699	496	7612	

TABLE 1.—Continued.

Lot 2, Pens 4, 6, and 7, Fed for Low Egg Production					
Months	Pounds Whole Grain	Pounds Mash	Pounds Semi-Solid Buttermilk	Number of Eggs Laid	Average weight of Birds in Pounds
1923 November	188	60	21	323	3.09
December	195	60		200	3.30
1924 January	245			39	3.34
February	237			175	3.23
March	244			429	3.32
April	221			259	2.89
May	171	146	33	842	2.57
June	171	154	38	1036	3.29
July	164	173	35	940	3.33
August	132	159	35	843	3.27
September	126	135	33	566	3.20
October	132	117	35	205	3.32
Total	2226	1004	230	5857	

Lot 1, which received the better balanced ration during winter, consumed 4089 pounds of grain, mash, and semi-solid buttermilk and laid 7,612 eggs, while Lot 2 consumed only 3,460 pounds of these feeds and laid 5,857 eggs. This illustrates the fact that the better the ration the more the fowls will eat and the better they will lay. It may be observed, also, that the maximum rate of egg production in the case of Lot 1 was during April and May, while with Lot 2 the maximum was reached about a month later.

The ration of whole grain only during January, February, March, and April had a marked effect upon the weight of the birds. On May 1, at the expiration of the period of exclusive whole grain feeding, the

birds in Lot 2 averaged 2.57 pounds in weight or nearly one-half pound less than they weighed six months earlier and this decrease had taken place in spite of the fact that they were fed all of the whole grain mixture that they would consume. On the other hand the birds in the other lot on the better balanced ration had an average weight of 3.63 pounds, or a difference in the weight of the fowls in the two lots of more than one pound per bird. With the addition of mash and semi-solid buttermilk to the ration for Lot 2 these birds rapidly increased in weight and also in the rate of egg production.

The influence of the two rations used during the four months on the mean weight of the eggs laid during that period has been discussed in West Virginia Experiment Station Bulletin No. 201 entitled, Some Factors Affecting the Weight of Eggs.

HATCHING THE EGGS

A white Leghorn cockerel was placed with each pen of 16 birds, and beginning a few days before and during the time when eggs were saved for hatching these males were systematically and regularly changed daily from one pen to another so as to avoid as far as possible the effect of any possible difference in the breeding abilities of the males.

Two hatches were made in Cyphers 400 egg incubators. For the first hatch eggs were saved from May 15 to May 20 and the incubator was started May 21. For the second hatch the eggs were saved from May 21 to May 26 and the eggs set on the following day. Table 2 gives the details of the two hatches.

TABLE 2.—Fertility and Hatchability of Eggs Laid by the Two Lots of Fowls.

Data Recorded for First Hatch	Lot 1	Lot 2
Number of eggs incubated	194	188
Per cent of eggs hatched	83	74
Per cent of eggs fertile	91	92
Per cent of fertile eggs hatched	91	80
Data Recorded for Second Hatch	**Lot 1**	**Lot 2**
Number of eggs incubated	192	207
Per cent of eggs hatched	88	85
Percent of eggs fertile	94	94
Per cent of fertile eggs hatched	93	90

The fertility was almost the same in the eggs from both lots of fowls. In the first hatch the hatchability was greater in the eggs from Lot 1, but in the second hatch the difference was slight.

RAISING THE CHICKENS

The chicks were toe marked and brooded in Mammoth brooders. Both lots ran together and were given free range. The birds were weighed individually on September 13 at which time those of the first hatch were 94 days old and those of the second hatch 88 days old.

Deaths from weakness or disease were reasonably low as only 5.7 per cent of the progeny of the fowls in Lot 1 died, and 2.5 per cent of Lot 2.

Table 3 shows the number of chicks weighed, the sex, and the mean weight of the birds hatched from eggs laid by the two lots of fowls.

TABLE 3.—Weight of Chickens on September 13, 1924, for the Two Hatches.

Data Recorded for First Hatch	Lot 1	Lot 2
Number of males	74	77
Number of females	69	54
Mean weight of males	$2.62 \pm .02$	$2.60 \pm .02$
Standard deviation in weight of males	$.236 \pm .013$	$.212 \pm .012$
Mean weight of females	$2.06 \pm .01$	$2.04 \pm .02$
Standard deviation in weight of females	$.145 \pm .008$	$.191 \pm .012$
Data Recorded for Second Hatch	**Lot 1**	**Lot 2**
Number of males	65	90
Number of females	86	78
Mean weight of males	$2.31 \pm .02$	$2.37 \pm .02$
Standard deviation in weight of males	$.244 \pm .014$	$.265 \pm .013$
Mean weight of females	$1.86 \pm .02$	$1.85 \pm .02$
Standard deviation in weight of females	$.193 \pm .010$	$.225 \pm .012$

The table shows that there was no significant difference in the weight of the chickens resulting from the two different ways of feeding the breeding stock. There also was no significant difference in variability in weight. The males averaged about one-half pound heavier than the females.

Second Year of Test

During the second year the experiment was conducted on the same lines as during the first year, with the exception that the rations were alternated as has been already explained.

Table 4 shows the amount of feed consumed, number of eggs laid, and the average weight of the birds during the second year of the test.

TABLE 4.—Feed Consumed, Eggs Laid, and Average Weight of Birds by Months for Lots 1 and 2 During the Second Year

Lot 1, Pens 5, 8, and 9, Fed for Low Egg Production					
Months	Pounds Whole Grain	Pounds Mash	Pounds Semi-solid Buttermilk	Number of Eggs Laid	Average Weight of Birds in Pounds
1924 November	142	118	34	77	3.40
December	139	111		11	3.43
1925 January	240			15	3.74
February	242			111	4.09
March	239			272	4.11
April	240			499	3.87
May	142	135	30	831	3.24
June	73	230	33	941	4.12
July	69	228	34	821	3.66
August	79	226	34	639	3.73
September 1st					3.62
Total (10 months)	1605	1048	165	4217	

TABLE 4.—Continued.

Lot 2, Pens 4, 6, and 7, Fed for High Egg Production					
Months	Pounds Whole Grain	Pounds Mash	Pounds Semi-solid Butter-milk	Number of Eggs Laid	Average Weight of Birds in Pounds
1924 November	142	119	34	63	3.15
December	141	113	34	10	3.32
1925 January	167	109	34	92	3.76
February	169	106	31	236	4.03
March	169	111	34	663	4.02
April	171	112	33	1005	4.04
May	143	140	34	1032	3.78
June	71	232	33	958	3.84
July	67	233	34	973	3.82
August	70	232	34	810	3.79
September 1st					3.63
Total (10 months)	1310	1507	335	5842	

Although the fowls of Lot 1 during January, February, March, and April were fed liberally, they consumed considerably less feed than the fowls in Lot 2, did not lay so well, and were slightly more than one-half pound lighter in weight at the end of that period. The maximum rate of egg production for Lot 2 was reached during April and May while with Lot 1 the maximum was reached about a month later.

HATCHING THE EGGS

All of the eggs laid by both lots of fowls from May 12 to 24, inclusive, were incubated in two 400 egg size Cyphers incubators. Table 5 gives the details of the hatch.

There was no appreciable difference in the fertility or hatchability of the eggs from the two lots of fowls.

TABLE 5.—Fertility and Hatchability of the Eggs During the Second Year.

Data Recorded for the Hatch	Lot 1	Lot 2
Number of eggs incubated	415	413
Per cent of eggs hatched	83	82
Per cent of eggs fertile	91	92
Percent of fertile eggs hatched	90	89

The two lots of chicks were toe-marked and then placed together in one flock. They were brooded in two Mammoth brooders and given free range during summer. The mortality from weakness or disease was reasonably low, the number of recorded deaths being 13 or 3.8 per cent for Lot 2 and 17 or 4.9 per cent for Lot 1.

WEIGHING THE CHICKS

The chicks were weighed individually on September 19, 1925, when they were 96 days old. Up to that time 5 had met accidental deaths, 25 had lost their distinguishing marks so that it was impossible to determine to which lot they belonged, and 48 were missing, probably having been caught by cats or crows. Table 6 gives the details of the weights of the 573 chicks remaining. This table shows that there was no difference in the weight of the chickens hatched from eggs laid by the two lots of fowls.

TABLE 6.—Weight of Chicks September 19, 1925.

Data Recorded	Lot 1	Lot 2
Number of males	133	124
Number of females	159	157
Mean weight of males	2.21±.02	2.20±.02
Standard deviation in weight of males	.28±.01	.26±.01
Mean weight of females	1.74±.01	1.76±.01
Standard deviation in weight of females	.21±.01	.22±.01

Conclusion

This experiment affords no evidence tending to show that a reasonably heavy egg production immediately prior to the hatching season has a detrimental influence on the fertility or hatchability of the eggs or on the vigor of the progeny.

Bulletin 208

August, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

Some Phases of the Relation of Temperature to the Development of Insects

(Technical)

By
L. M. PEAIRS

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
HENRY G. KNIGHT, Ph. D. .... Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr., ... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist

E. P. Deatrick, Ph. D. — Associate Agronomist (Soils)

T. E. Odland, Ph. D. — Associate Agronomist

T. C. McIlvaine, Ph. D.† — Assistant Agronomist (Soils)

D. R. Dodd, M. S. — Assistant Agronomist

M. M. Hoover, M. S. — Junior Agronomist

H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman

Chas. V. Wilson, M. S. — Assistant Animal Husbandman

J. H. Longwell, M. S. — Assistant Animal Husbandman

J. H. Rietz, D. V. M. — Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist

Chas. E. Weakley, Jr., B. A. — Assistant Chemist

L. P. Hansen, Ph. D. — Assistant Chemist

T. B. Leith, B. A.** — Assistant Chemist

Paul Daughenbaugh — Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr. — Dairy Husbandman

H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman

G. Malcolm Trout, M. S. — Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist

W. E. Rumsey, B. S.** — State Entomologist

L. E. Dills, M. S.** — Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist

Paul A. Eke, Ph. D. — Assistant Farm Economist

F. D. Cornell, Jr., M. S. — Junior Farm Mechanician

W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M. — Home Economist

Hazel C. Cameron, M. S. — Research Specialist in Foods

Nell Nesbitt, A. M. — Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D. — Horticulturist

H. L. Crane, M. S. Agr. — Associate Horticulturist

K. C. Westover, M. S. Agr. — Assistant Horticulturist

Ernest Angelo, M. S. Agr. — Junior Horticulturist

L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist

H. P. Sevy, M. S. Agr. — Assistant in Horticulture

M. B. Hoffman, M. S. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist

Anthony Berg, M. S. — Assistant Plant Pathologist

L. H. Leonian, Ph. D. — Assistant Plant Pathologist

E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

E. T. Wightman, M. S. Agr. — Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D. — Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D. — Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Some Phases of the Relation of Temperature to the Development of Insects

Investigators early in the modern scientific era recognized the influence which temperature exerted upon the rate of growth ir plants. Reaumur, as early as 1735, recognized this relation as a quantitative one and suggested the idea that the total amount of heat, expressed as temperature summations, required to produce a given growth effect, was a constant. The method of summation, as used by Reaumur, assumed that temperatures above the zero of his thermometer, *i. e.*, the freezing point of water, were effective while those below zero were not.

Variations in the experimentally determined thermal constants were later associated with the effect of other climatic factors in the processes of growth and led to the search for more accurate methods for the summation of temperatures. Credit appears to be due de Candolle (1832, *vide* de Candolle 1855) for the statement that effective temperatures do not necessarily persist down to zero but that some point above zero should often be used as the basis for summations of the thermal increment.

From the time of de Candolle's early work progress for some fifty years was mostly in the line of accumulation of statistics in which many investigators participated.

Van Oettingen (1879) seems to have been the first to recognize the straight line relationship of the coefficients of velocity increase in the rate of growth. As the "threshold of development," a term also apparently first used by Van Oettingen, he assumed several possible temperatures, all within the limits of the possible course of the straight line, and from each of these computed the thermal

---

The project reported in this report was, in its conception, a continuation of work begun by Dr. Dwight Sanderson at the New Hampshire Agricultural Experiment Station, and by him transferred to the West Virginia Agricultural Experiment Station, where it was continued by the writer. During the year 1916-1917 the work was done in the Zoological Laboratories of the University of Chicago. Later it was continued in the entomological laboratory at the West Virginia Agricultural Experiment Station.

Acknowledgements are due to Dr. Sanderson for advice and assistance at the beginning of the project and for continued interest throughout; to the members of the faculty in Zoology at the University of Chicago who have contributed in various ways to the progress of the work.

increments for each point on the line. The zero point which gave values for the thermal increments at the several points which were most nearly in agreement was assumed to be the actual threshold. This method does not differ in principle from that used in this paper and will give results approximately the same as the method of least squares.

Investigators working with eggs of silk worms early recognized the influence of temperature in the time of hatching (Beauvais, 1837, and numerous others). Whether they or the fish culturists were the first to recognize the influence of temperature on cold blooded animals as similar to that observed with plant growth is not certain but it was early clearly brought out in the works of the fish culturists: Green (1870), Dannevig (1894), Wallich (1900), Reibisch (1902), and others.*

Fere (1894) and Edwards (1902) have shown that warm blooded animals may be subject to a similar effect of temperature variations as they demonstrated that the rate of development of the egg of the domestic fowl depends directly upon the temperature at which it is incubated.

The law of van't Hoff (1884) and Arrhenius' (1889) formula based upon it, demonstrated the relation of the velocity of chemical reaction to the degree of heat and showed that the coefficient for the increase in velocity was frequently between two and three for each ten degree increase in temperature. These formulations, coming as they did at a time when biologists had turned to physics and chemistry for the explanation of vital phenomena, have had a rather profound influence on the interpretations of temperature data from the beginning of the present century. Lillie and Knowlton (1897) showed that the coefficients for the increase in velocity of the development of eggs of Amphibians decreased with increased temperatures and this agrees with the van't Hoff coefficients. Many later workers, mostly in the botanical field, have found that the variations observed in rate of growth can most readily be explained in terms of this law, assuming generally that the coefficient is nearly the same for each ten degree temperature change. Lehenbauer (1914) found no better way to describe his results with the growth of maize seedlings; Livingston applied the law of van't Hoff but, for practical purposes, supplemented it with certain physiological indices furnished by living plants.

---

*Kupfer (1876) denied any influence of temperature upon time of hatching of fish eggs.

Reibisch (1902) in his work with fish eggs described the developmental curve as an hyperbola and calculated, from the formula of the curve, the point which should represent the threshold of development and from which thermal constants or thermal increments should be computed. He showed also that development is possible, with fish eggs of some sorts, below the centigrade zero, provided the density of the solution is great enough to prevent freezing. Some years later Sanderson and Peairs (1914) and Krogh (1914) arrived independently at conclusions essentially identical with those of Reibisch. Krogh and Johannsen (1914), and Krogh (1914) based their conclusions on work with insects, amphibians, echinoderms, and fishes, while Sanderson and Peairs worked with several different kinds of insects.

Loeb and Northrup (1917) showed further evidence of the straight line relationship but their work indicated, as did the earlier work of Krogh, some departure from the straight line condition near the base of the curve. Krafka (1920) discussed the possibility of interpreting this aberration as an entirely different type of curve. It was Shelford (1917) however, who first pointed out the fact that this type of departure from the straight line was rather general and indicated the necessity for a more adequate interpretation of it than had yet been offered.

That temperature affects other vital processes in essentially the same manner as it affects growth and development has been indicated by many investigators. Snyder (1908 and 1911) showed that the conductivity of muscle fibre was affected; Rogers (1911) demonstrated the same for the rate of heart beat; Loeb and Wasteneys (1911) showed that the temperature relation for the oxygen consumption and carbon dioxide production of eggs of Arbacia was similar to the relation of temperature to development; and Krogh (1914 and 1916) showed the same for the carbon dioxide production of insects.

Several other physiological processes have been shown to be affected but the data is not such as to permit the demonstration of the analogy in all cases.

The foregoing statements cannot be said to cover the work which has been done on the subject. Valuable summaries will be found in the works of Bachmetjew (1901 and 1907), Abbe (1905), Kanitz (1915), and Shelford (1917). More or less direct applications of the principles involved will be found in Merriam (1894),

Hopkins (1900, 1918, and 1919), Sanderson (1908 and 1910), and in many American entomological studies of recent years. Mention of these papers will be found in the bibliography.

EXPERIMENTAL WORK

Objects

The experiments herein reported were designed to determine:

1. The developmental curves for insects reared at different constant temperatures.

2. Whether a constant threshold of development can be experimentally demonstrated and, if so, the method for its determination.

3. The validity of the theory of the "Thermal Constant," and assuming such a constant, the correct method for its determination.

4. The differences in the effects of constant temperatures and of variable temperatures upon growth and development.

5. The correlation of the production of carbon dioxide with the rate of development at different temperatures.

6. Whether minor variations in other factors, such as light and moisture, have a sufficiently great influence upon rate of development to affect materially the interpretation of results based upon temperature variations alone.

Explanations of Terms Used

1. *Effective temperature*: All temperatures within the experimentally determined range where development may take place.

2. *Thermal constant*: The total of effective temperatures, expressed in day-degrees, to which the organism is subjected during the developmental period under consideration.

3. *Day degrees*: One degree of temperature above the zero for the developmental curve, enduring for a period of one day, constitutes a day-degree.

4. *Zero of velocity curve*: The point at which the curve of velocity of development intersects its temperature axis.*

---

*This is the "Developmental Zero" of Sanderson and Peairs (1914) and has been termed "Physiological zero", "Critical point", and "Threshold of development." All of these terms, used in this connection, are inexact and capable of misinterpretation.

5. *Threshold of development*: This term indicates the temperature at which, on the descending scale, development definitely ceases and at which, on the ascending scale, development is again initiated. This point may or may not correspond with the zero of the velocity curve but since there is evidence which indicates that the two points are not the same in all cases, it is desirable to keep the terms separate. The term is here used in the sense of Shelford, Reibisch, and Von Oettingen.

6. *Hyperbola*: A curve in which the product of the two factors upon which any point upon the curve is based is constant. The formula for such a curve is $X \times Y = C$.

7. *Reciprocal curve:* These are formed by plotting the reciprocal value of the time factor against the temperature factor. Such a reciprocal value of the time factor expresses the value of one day in terms of percent of development. The reciprocal for a perfect hyperbola is a straight line. The approach of the points on the reciprocal curve to the straight line, therefore, indicates the relation of the developmental curve to the true hyperbola. This curve shows the *rate of acceleration* of development.

8. *Index line, or index of development*: This is the same as the reciprocal curve. Any point on this line indicates the rapidity of development at the temperature corresponding.

9. *Factor or index number*: The value of one day expressed in percent of the whole period required. This may be read directly on the index line.

10. *Exponential curve*: A curve whose points are established by treating the time values, determined experimentally, with some factor or exponent so that their relative magnitude is changed. Such a curve would be necessary to express the velocity of development if the value of a degree at one point within the developmental range should prove to be different from that of a degree at some other point. In such event, factorial treatment of the recorded temperatures would be necessary in order to derive the true constant.

11. *Optimum temperature*: The temperature at which the greatest percentage of insects are able to complete normal development. This is not usually the temperature at which development takes place with the greatest velocity.

Methods of Presenting the Data

The most convenient and useful methods of presenting data of the type included in this report is by means of tables and graphs. Explanations accompany the tabulated material and the method of constructing the graphs follows.

Curves showing the relation of the time factor to the temperature at which development takes place were constructed directly from the data and have been found to approximate the hyperbola in form. A more instructive presentation, and the one here followed, has been to plot the reciprocals of the time factor, showing the comparative values of a day at the different temperatures. Such curves show directly the relation between the increase in velocity of development and change in temperature. Inspection of these curves shows that they approach the straight line; it has seemed more satisfactory to show the relation of the points of the curves to a straight line than to plot the actual curves. The best fitting straight line has, therefore, been determined by the method of "least squares." Such straight lines have been considered, in discussions of the data, as the curves of velocity of development. The points on all curves have been established from points which represent weighted averages. These give due consideration to the varying numbers of individuals in each emergence record. Any point, as finally established is a component of all emergence records for the temperature. Similarly, each point is given a weighted value in the determination of the course of the final best-fitting straight line.

The zero point, as has been stated before, used in the calculation of thermal increments, is that point at which the straight line curve thus established, intersects the temperature axis.

Description of Experiments

MATERIALS USED

Experimental work involved in this paper deals with insects of the following groups:

Lepidoptera: the codling moth, *Carpocapsa pomonella* Linn., pupae; the corn earworm, *Chloridea obsoleta* Fabr., larvae and pupae; the cabbage butterfly, *Pontia rapae* L., larvae and pupae; *Malacosoma americana* Fabr., the tent caterpillar, pupae; **Coleoptera:** the Colorado potato beetle, *Leptinotarsa 10-lineata* Say, eggs, larvae, and pupae; **Diptera:** the house fly, *Musca domestica* L., larvae and pupae; *Lucilia caesar* L., the green-bottle fly, larvae and pupae;

Calliphora vomitoria L., the bluebottle, larvae and pupae; *Sarcophaga carnaria* L., (?) a flesh fly, larvae and pupae.

In addition to these, many insects were studied which do not appear in this report for the reason, usually, that not enough points on the developmental curve were established to make the results of value in the conclusions drawn. None were omitted because preliminary evidence was of a discordant nature.

SOURCES OF EXPERIMENTAL MATERIAL

All insects used in the experiments reported herein have been collected at Morgantown, West Virginia. Fly eggs were collected from meat exposed for that purpose. The collections of this material extended over a period of several years and may be supposed to represent all the usual variations to be encountered in field collected material which may be due to seasonal variation, variation from year to year, and individual variation in the parent insects. Larvae were hatched in the laboratory from the eggs thus collected. The time of hatching of all eggs used in experimental work was recorded accurately within one hour. Pupae were usually secured from cultures allowed to develop on food provided but kept under outdoor conditions; only rarely were pupae from incubator raised material used. When such pupae were used they were always from the incubators within which moderate temperatures were maintained, *e. g.*, 15° or 20°. The time of pupation was known always within three hours, usually within one or two hours, and always within one hour when the insects were to be placed in incubators at high temperatures.

Sarcophaga larvae were taken from exposed meat where the time of their deposition was known within one hour.

Chloridea obsoleta larvae were collected in the field and the age of the young larvae was not definitely known but all those used were less than one-fourth inch in length and as nearly uniform in size as it was possible to secure them. Pupae of this insect were from larvae collected in the field but allowed to pupate in the laboratory.

Carpocapsa pomonella pupae were from larvae collected during June and July and were all, presumably, those which form what is known as the first brood. Time of pupation was observed within three hours in all material used.

Malacosoma americana pupae used were from larvae reared in the laboratory, the time of pupation of which was known within six hours.

Leptinotarsa 10-lineata eggs used were those the deposition of which had been observed and larvae were from such eggs hatched in the laboratory. Pupae were from field collected larvae allowed to pupate in the laboratory.

APPARATUS USED

Specially constructed incubators of square form and having a capacity of about two cubic feet were used throughout the work. Those designed to maintain temperatures above room temperature were kept in the laboratory; those for temperatures of 15° and 20° were kept inside a large refrigerator while those at 12° and lower temperatures were kept in a cold storage room during the greater part of the course of the experiments although at times these also were kept in the large refrigerator.

Heat was supplied by small electric light bulbs, blackened. Two and four candle power, carbon filament bulbs were used. In order to secure uniform distribution of the heat four or six of these bulbs were used in each incubator. The bulbs were so placed as to give the most even distribution of the heat throughout the chamber. Heat control was by means of thermostats, several types having been used but none giving better control than a small, simple, bi-metallic type. These maintained temperatures which did not vary, in any of the experiments recorded, more than about one-half degree centigrade above or below the desired temperature.

Thermometers of several types were used. Each incubator was supplied with a maximum and minimum thermometer calibrated against a Bureau of Standards certified thermometer. These indicated merely the variation, the temperature being recorded from a large thermometer reading to tenths of degrees and kept with its bulb as nearly as possible in the center of the insect containers in the incubator at the time. At intervals of about a week the variability of the temperature was further checked by keeping a thermograph in the incubator for two days.

No records were kept of material when the temperature varied more than one degree Fahrenheit above or below the desired temperature so the experimental error due to temperature variations may be considered as less than five-ninths of one degree Centigrade. The method of recording the temperatures from the part of the incubator in which the insect material was located reduces the possibility of error from variations within the incubator although repeated tests of the temperature in different parts of the incubators showed that such variation was never great.

Material within the incubators was always so supported as to allow free circulation of air below and around it but no other provision was usually made to secure circulation. In early tests circulation was provided by small electric fans but since no apparent difference in results was obtained by this method it was discontinued.

No attempt was made to keep the relative humidity constant but it was usually maintained at near the point of saturation. Wet and dry bulb thermometers were used to measure the degree of moisture. Semi-automatic devices feeding water onto large wicks suspended around the heating bulbs supplied atmospheric moisture. In some of the experiments with caterpillars it was found that the moisture was injurious and the incubators were allowed to become somewhat dryer inside, the moisture ranging from not less than 40 to about 65 per cent relative humidity.

In practically all the work reported the insects were kept in complete darkness or in very dim light.

METHODS OF HANDLING MATERIAL

Since the bulk of the material used in these studies was fly larvae and pupae, the description of methods here given applies to that material. In case methods were varied in the manipulation of the material, mention is made of the variation.

Fly larvae, excepting *Sarcophaga,* were secured from eggs hatched in the laboratory, as has been stated. Usually the hatching was actually observed so that the time was known exactly; in a few instances the time was not known within from one to three hours. Ordinarily such material was placed in the cold incubators so that the slight variable introduced would have proportionately less effect in the result since the developmental period in the cold incubators was so long that the one or two hours variation at the start would be "absorbed" without affecting materially the value of the results. No larvae were permitted to feed before being placed in the incubators. This further reduced the chance for any effect from variation in the length of time from hatching to entrance into the incubators.

Food supplied for the fly larvae was lean beef of which an excess was always furnished. When the feeding period occupied less than one week this was not renewed. Usually when the period of feeding extended for more than a week the food was changed

once in about five days. Larvae eating foliage were supplied with fresh food once or more each day and were transferred by hand from the old food to the fresh.

Food for the flies was half buried in moist sand and kept covered with moist blotting paper. Various containers were tried but the ones most used were tubes one inch by three inches with bottoms of plaster of paris about one-fourth inch thick. These were sunk in moist sand, the plaster bottoms of the tubes usually absorbing moisture enough to keep the sand within them in moist condition. The tubes were stoppered with cotton or with perforated plaster. From twenty-five to one hundred larvae, usually the smaller number, were kept in each tube. When all had ceased to feed and entered the "pre-pupal stage," the food was removed and sand added. Pupation took place in the sand and observations were so arranged that the time of pupation was recorded within six hours, except in lots where the development extended over periods exceeding twenty days when the observations were sometimes made only twice daily.

Pupae were kept in tubes similar to those in which the larvae were reared or in broad flat cylinders with plaster bottoms and wire screen covers. About one inch depth of sand was kept in the bottoms of the large containers and somewhat more in the smaller ones. The pupae were covered with about one-half inch of moist sand. Emergence records were kept for the pupae similar to the pupation record for the larvae.

All larvae and pupae were counted although it was found that sufficiently accurate estimations of the numbers might have been secured by weighing.

The sand in the breeding containers was generally kept sufficiently moist by absorption through the plaster bottoms from the wet sand outside but daily examination was made and when they were apparently not absorbing enough water more was added directly, so that the medium, food or sand, was moist at all times. Since the sand used was always sterilized by dry heat and only distilled water was used little trouble from molds was encountered although this treatment did not provide entirely aseptic conditions.

Larger containers, usually lantern globes, were used for caterpillars and their pupae.

Codling moth larvae were placed between sheets of glass separated by about the thickness of the larvae so that their pupation

could be observed directly without removing them from their cocoons for examination.

Throughout the work, when temperature or other conditions within the incubator were not according to the standard, or when observations were missed during a critical period so that there was any doubt as to the duration of the stage, the time of first emergence, or any other important fact, the lots of insects involved were discarded.

Numbers of insects used are indicated in the tabulated summaries of results. These numbers were large enough in most cases, so that minor variations in material or occasional errors of observations should not affect the general results.

Conditions approximating variable temperature conditions were secured by moving insects from one constant temperature chamber to another at intervals of six or twelve hours. Less frequent changes did not, apparently, furnish conditions comparable to outdoor condition.*

Outdoor conditions were maintained in a screened breeding cage kept in a shaded situation and having the temperature recorded by a thermograph.

EXPERIMENTAL DATA

Constant Temperatures

In the experiments with constant temperatures, insects were maintained at different constant temperatures, each lot being kept at one temperature throughout its period of development. Temperatures ranging from 5°C. to 35°C. at five degree intervals, with a few lots at 6.5°, 8°, 12°, and 40° are reported. Many low temperature lots from temperatures which later were found to be below the threshold of development have been omitted from the summaries because they showed no evidence of development. The same is true for high temperatures. Evidence of considerable development at 40° or higher temperatures was rare and no mention is made of the many lots incubated at such points.

Data are available usually for the establishment of six or more points upon a developmental curve. A considerable number of intermediate points have been established by observations of insects in much smaller numbers than are represented by most of the lots reported. These have been omitted because the numbers are not

*A special thermostat so constructed as to provide temperatures varying in any desired manner during the day was devised but some difficulties in cooling the incubator were encountered; later these were overcome but no insects reared in this incubator are here recorded.

comparable to the others and because they do not add anything of importance to the report.

The results reported, based upon work with the four species of flies, may be considered as the most significant part of the evidence because of the number of insects involved and because the possibility of variation in factors other than temperature was less with the fly material.

The results are presented in tabular form on the following pages. The presentation, in connection with the tables, of "Thermal Constants" and of temperature, or effective temperature, summations based upon the interpretation of the velocity curve as a straight line should not be taken to imply a fixed preformed conviction that this was the correct interpretation. It has merely been found convenient, in the tables and in the graphs, to show the relation of the experimentally established points to the straight line and the relation of the termal increments to a constant. What the significance of these relations may be will be brought out in the discussion of the data.

The possibility that the time of first emergence of individuals at different temperatures may be a more exact index of the effect of temperature than the mean emergence time has led to the inclusion of summaries based on first emergence along with those based upon mean emergence. This first emergence data represents the average time of first emergence, usually from many separate lots of individuals subjected to the same treatment, rather than the absolute minimum emergence time.

In the tabular summaries are given the temperatures; the developmental time in days; the accumulated temperatures based upon the summation of daily temperatures above the zero point indicated by the velocity curve, accumulated temperatures and thermal constants being expressed throughout this work in day-degrees; the standard deviation (also in day-degrees) for the developmental time factor based upon all individuals emerging; the standard deviation for the accumulated temperature based upon the averages for the several separate lots comprised in each summary; standard deviations for time and for the thermal increment based upon first emergences calculated in the same manner as those for the mean emergences; and the index of development based on mean emergence as well as that based upon the first emergence. Thermal constants based upon the mean emergence velocity curve and upon the first emergence velocity curve are also given.

TABLE 1.—Lucilia caesar, larvae. Constant temperatures (See Fig. 1).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	14,654	46	3.5	3.7	.21	109°	6 3°	102.5°	3.1°	27 0	28.6
30	15,100	71	4.2	4.4	.23	108	5.6	102 1	2.2	22.5	23.8
25	14,120	79	5.25	5.3	.27	103	5 2	103.2	2.0	18 6	19 0
20	17,340	89	7.0	7.4	.18	107	2 6	100.1	3.1	13 6	14.3
15	11,600	84	11.1	12.0	.29	114	4.7	103 2	1.9	8.4	9 0
10	12,300	54	24.9	26.5	1.2	119.	5.4	107 1	3 3	3.9	4 0
8	4,300	36	47.4	49.5	3.0	123	7.6	109.0	4.2	2.0	2.1
6.5	2,000	5.2	135.	136.	2.2	136	2 2	108.0	1.9	.73	.74
5	5,400	0									

Thermal constant of curve: Mean, 110.7°, S. D., 3.9°; Ave. Min., 103.0°, S. D., 2.6°. Zero of curve: Mean, 5.5°; Ave. Min., 5.7°.

Fig. 1.—Velocity of development of Lucilia caesar larvae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 1.)

TABLE 2.—Lucilia caesar, pupae. Constant temperatures (See Fig. 2).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	12,400	57	3.9	4.2	.31	121°	8.8°	110.0°	3.6°	24.0	25.6
30	14,200	65	4.6	5.1	.34	119	8.0	106.0	2.2	19.5	21.8
25	9,800	81	5.7	6.5	.46	120	8.5	103.7	2.0	15.5	17.5
20	13,900	89	7.8	9.2	.86	125	11.6	103.0	2.3	10.8	12.8
15	9,200	83	12.3	14.5	1.63	123	13.8	100.9	3.0	6.8	8.1
10	8,000	67	34.0	38.0	3.34	133	12.0	108.8	4.4	2.6	2.9
8	1,600	7	94.8	100.0	14.70	150	22.0	113.8	5.2	1.0	1.1
5	4,000	0									

Thermal constant of curve: Mean, 122.8°, S. D., 9.2°; Ave. Min., 104.8°, S. D., 3.6°. Zero of curve: Mean, 6.5°; Ave. Min., 6.8°.

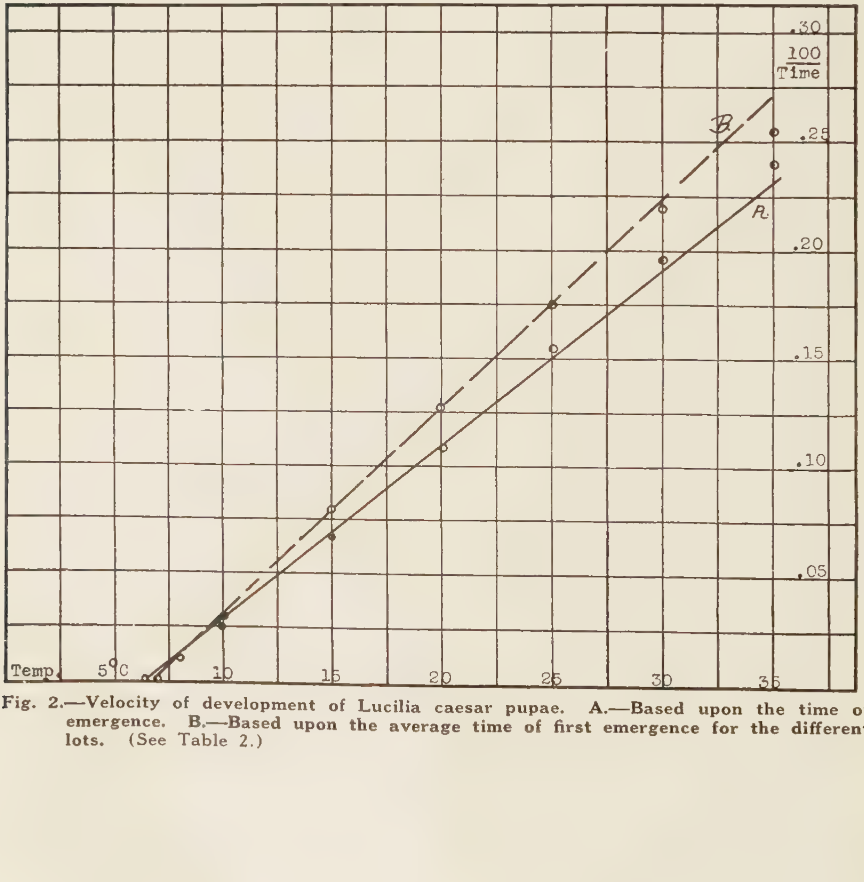


Fig. 2.—Velocity of development of Lucilia caesar pupae. A.—Based upon the time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 2.)

TABLE 3.—Calliphora vomitoria, larvae. Constant temperatures (See Fig. 3).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	9,800	39	3.2	3.4	.46	98.6°	4.3°	93.4°	2.2°	29.0	31.2
30	8,400	64	3.9	4.4	.31	105.6	5.2	94.4	2.0	23.0	25.6
25	14,000	83	4.8	5.4	.29	104.5	4.7	92.16	2.6	18.5	20.8
20	14,700	92	6.6	7.3	.33	102.2	3.9	93.7	1.8	13.7	15.1
15	11,400	82	10.5	11.7	.98	105.0	4.9	96.6	3.3	8.1	9.5
10	10,900	59	23.0	27.3	2.00	109.2	4.6	96.6	4.1	3.7	4.3
8	2,350	33	44.6	56.0	5.80	112.0	6.1	98.1	3.8	1.8	2.2
5	3,300	0									

Thermal constant of curve: Mean, 104.7°, S. D., 6.9°; Ave. Min., 94.5°, S. D., 3.1°. Zero of curve: Mean, 6°; Ave. Min., 5.8°.

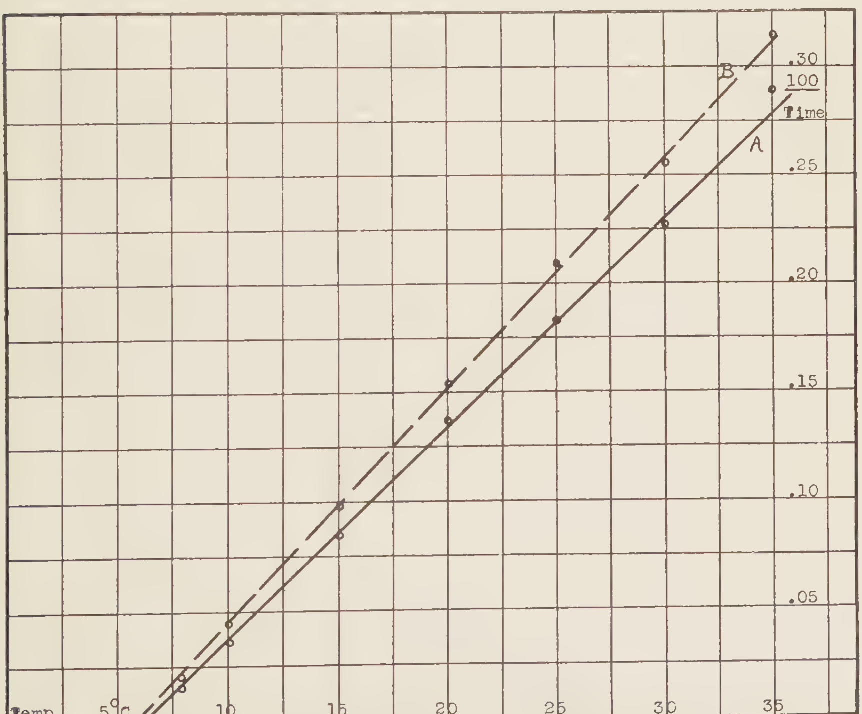


Fig. 3.—Velocity of development of Calliphora vomitoria larvae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 3.)

TABLE 4.—Calliphora vomitoria, pupae. Constant temperatures (See Fig. 4).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	Min.	S. D.	S. D.	Mean	Min.
35°	7,000	54	4.2	4.6	1.9	128.0°	4.7°	116.3°	3.2°	21.8	23.8
30	9,500	63	5.1	5.8	.33	133.4	5.5	115.8	4.2	17.2	19.6
25	9,950	82	6.5	7.0	.31	126.0	2.5	114.0	3.0	14.3	15.3
20	11,650	92	8.9	9.4	.70	124.0	7.1	113.0	3.3	10.6	11.2
15	10,100	87	15.	16.9	1.49	135.2	8.3	115.5	4.2	5.9	6.7
10	10,500	43	44.3	46.7	4.5	140.1	12.6	119.6	7.1	2.1	2.2
8	3,000	1	156.2	157.	.19	157.3	.4	109.3	.1	.6	.63
5	4,300	0									

Thermal constant of curve: Mean, 130.1°, S. D., 5.7°; Ave. Min., 114.8, S. D., 2.3°. Zero of curve: Mean, 7°; Ave. Min., 7.3°.

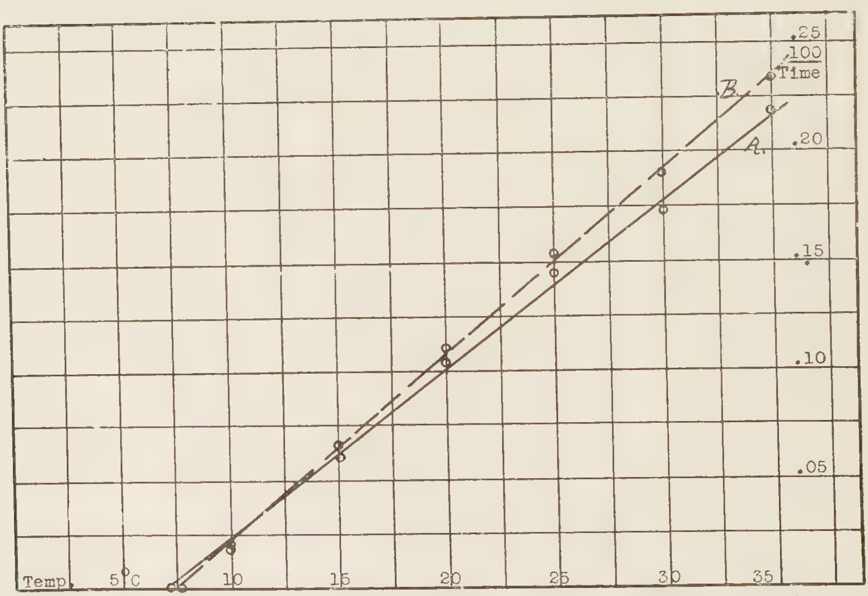


Fig. 4.—Velocity of development of Calliphora vomitoria pupea. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 4.)

TABLE 5.—Musca domestica, larvae. Constant temperatures (See Fig. 5).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	2,550	75	4.4	4.5	.27	128°	5.4°	125.4°	2.3°	22.0	22.7
30	2,000	86	5.3	5.6	.36	133	5.4	124.6	2.1	18.0	18.9
25	2,024	94	6.8	7.2	.41	133	4.9	125.8	3.0	13.9	14.7
20	2,500	97	9.0	9.6	.39	130	5.3	121.5	2 4	10 4	11.1
15	2,412	78	14.4	15.2	.92	129	6 9	122.4	3.6	6.7	6.9
10	2,016	72	33.1	34.0	4.7	119	16.7	115.65	4.2	2.9	3.0
8	500	6	90.1	90.3	.9	136	1.6	135.1	.1	1.1	1.1
5	2,300	0									

Thermal constant of curve: Mean, 129.9°, S. D., 6.9°; Ave. Min., 124.3°, S. D., 3.8°. Zero of curve: Mean, 6.5°; Ave. Min., 6.5°.

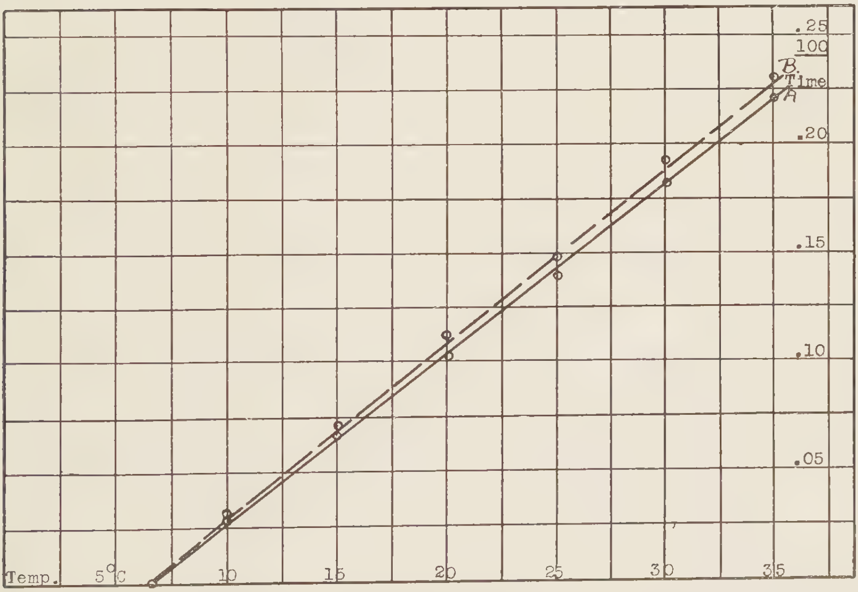


Fig. 5.—Velocity of development of Musca domestica larvae. A.—Based upon the mean time of development. B.—Based upon the average time of first emergence for the different lots. (See Table 5.)

TABLE 6—Musca domestica, pupae. Constant temperatures (See Fig. 6).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	1,470	65	3.7	4.0	.15	112°	2.1°	107.2°	1.1°	25.0	26.3
30	2,900	88	4.6	4.9	.26	113	1.9	106.7	.4	20.4	21.7
25	2,644	87	5.6	5.9	.44	106	3.6	101.9	2.9	17.0	17.9
20	3,025	96	7.8	8.25	.80	107	7.4	103.0	3.6	12.1	12.8
15	2,650	83	13.2	15.4	1.23	123	13.0	108.2	5.0	6.5	7.6
10	3,000	71	32.2	35.7	4.2	107	12.5	103.0	3.1	2.9	3.1
8	600	20	92.0	127.0	11.1	127	11.1	110.4	......	.8	1.08
5	1,140	0									

Thermal constant of curve: Mean, 112.7°, S. D., 7.1°; Ave. Min., 105.3°, S. D., 3.3°. Zero of curve: Mean, 7°; Ave. Min., 6.8°.

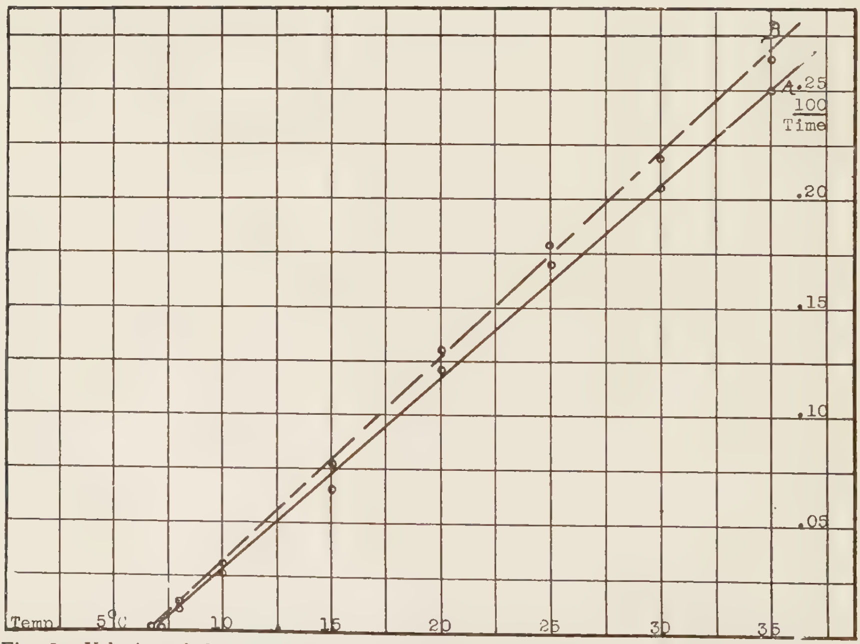


Fig. 6.—Velocity of development of Musca domestica pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 6.)

TABLE 7.—Sarcophaga carnaria (?) larvae; constant temperatures (See Fig. 7).

T.	No. of Insects	Perc't. Developed	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
40°	200	23	2.9	3.0	.07	97.5°	.36°	95.9°	......°	33.0	33.9
35	750	68	3.45	3.6	.18	99.0	.54	94.9	......	27.5	29.0
30	900	74	4.2	4.3	.06	97.5	.38	94.5	......	23.5	23.8
25	840	80	5.4	5.5	.05	96.0	.31	94.5	......	18.0	18.5
20	1,100	74	7.5	8.0	.36	100.0	1.88	93.8	.47	12.5	13.3
15	980	68	12.2	14.3	1.1	107.0	2.66	93.5	.82	7.0	8.2
12	360	35	20.9	22.0	.96	99.0	7.2	94.5	.15	4.5	4.9
10	890	29	40.0	44.0	2.11	110.0	13.0	100.0	.25	2.3	2.5
5	400	0									

Thermal constant of curve: Mean, 99.7°, S. D., 1.3°; Ave. Min., 94.3°, S. D., .21°. Zero of curve: Mean, 7°; Ave. Min., 7.5°.

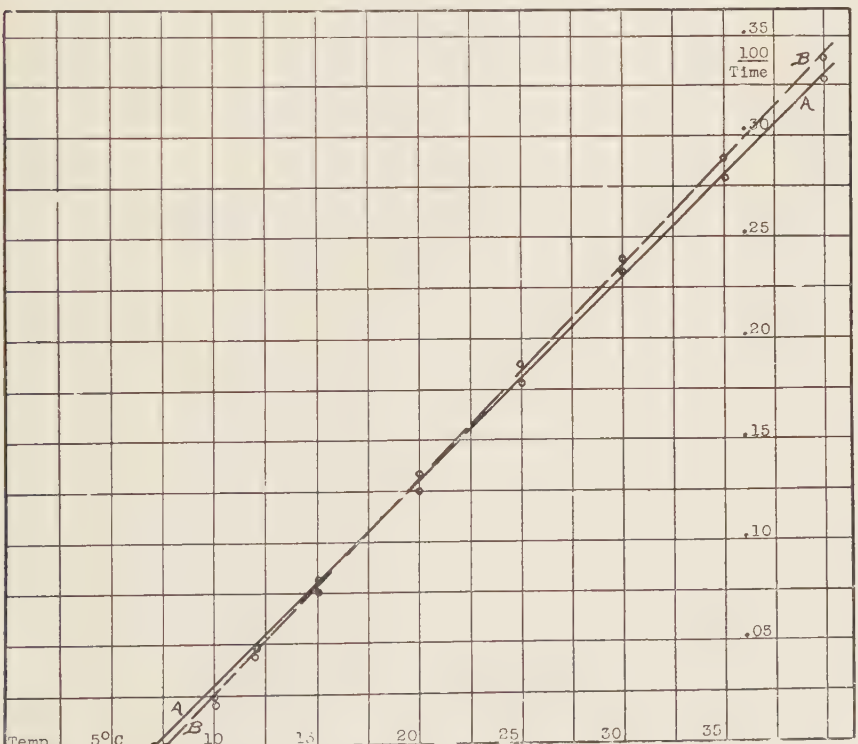


Fig. 7.—Velocity of development of Sarcophaga carnaria (?) larvae. A.—Based upon the mean time of pupation. B.—Based upon the average time of first pupation for the different lots. (See Table 7.)

TABLE 8.—Sarcophaga carnaria (?), pupae. Constant temperatures (See Fig. 8).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
40°	300	29	3.75	3.8	.12	127°	3.9°	113.6°	1.7°	25.4	26.7
35	500	71	4.1	4.5	.2	128	5.6	114.8	1.3	22.0	24.4
30	560	81	5.1	5.8	.27	134	6.2	117.3	2.3	17.8	19.6
25	500	86	6.3	6.5	.19	120	4.5	113.4	.3	15.4	15.9
20	570	87	8.4	9.0	.34	121	7.2	109.2	.7	11.0	11.9
15	525	71	14.6	16.2	.88	138	9.2	116.8	1.3	6.1	6.85
10	456	37	42.0	48.0	2.86	162	13.3	126.0	1.1	2.1	2.4
5	250	0									

Thermal constant of curve: Mean, 129.25°, S. D., 6.7°; Ave. Min., 114.3°, S. D., 1.8°. Zero of curve: Mean 6°; Ave. Min., 7°.

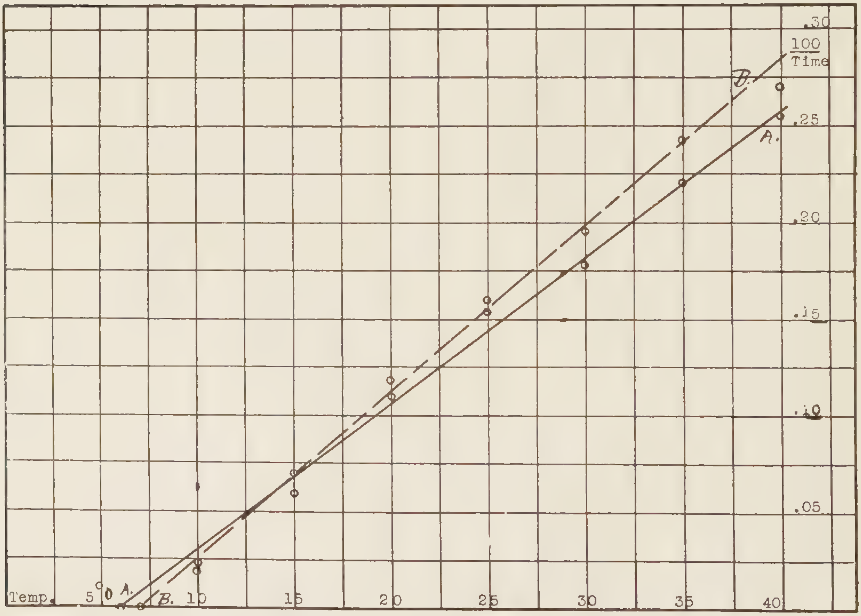


Fig. 8.—Velocity of development of Sarcophaga carnaria (?) pupae. A.—Based upon the time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 8)

TABLE 9.—Chloridea obsoleta, larvae. Constant temperatures (See Fig. 9).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	100	14	7.8	8.0		240°		234°		12.5	12 8
30	200	32	9.0	9.6		240		225		10.4	11.1
25	200	36	11.4	12.2		245		228		8 1	8 8
20	200	40	14.2	15.2		229		211		6 5	7.0
15	200	46	21.0	22.3		224		211		4.4	4 7
10	200	25	48.0	53.0		265		240		2.3	2.4
5	100	0									

Thermal constant of curve: Mean, about 240°; Ave. Min., about 220°. Zero of both curves is 5° but this is doubtless too low.

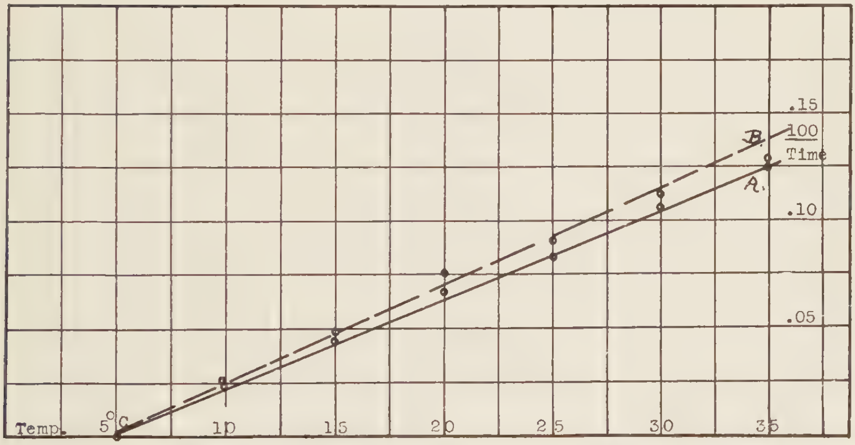


Fig. 9.—Velocity of development of Chloridea obsoleta larvae. A.—Based upon the mean time of pupation. B.—Based upon the average time of first pupation for the different lots. (See Table 9.)

TABLE 10.—Chloridea obsoleta, pupae. Constant temperatures (See Fig. 10).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	350	9	12.0	12.5	.88	337.5°	23.6°	330.0°		8.0	8.3
30	350	49	13.4	13.8	.72	301.4	22.7	301.5	8.4°	7.2	7.5
25.5	350	56	15.6	16.8	.49	294.0	8.5	288.0	6.6	6.0	6.4
20	400	62	22.0	23.5	1.3	281.0	16.3	275.0	3 0	4.3	4.5
15.5	350	55	32.5	39.0	3.7	292.0	27.8	260.0	5.8	2.5	3.1
11	350	26	90.0	98.0	2.2	300.0	6.6	315.0	2 0	1.0	1.1

Thermal constant of curve: Mean, 306°, S. D., 15.4°; Ave. Min., 295°, S. D., 3.8°. Zero of curve: Mean, 8°; Ave. Min., 7.5°.

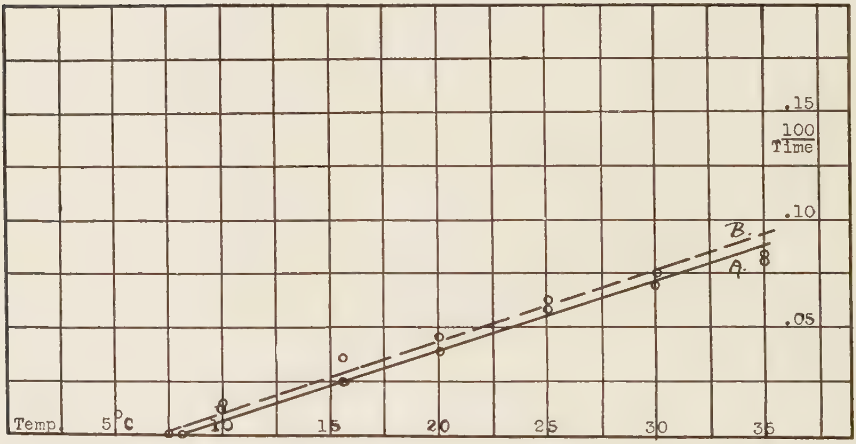


Fig. 10.—Velocity of development of Chloridea obsoleta pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 10.)

TABLE 11.—Pontia rapae, larvae. Constant temperatures (See Fig. 11).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	150	Larvae all died from fungus disease.									
30	200	60	8.0	8.25	.62	206°	15.4°	200°	2.0°	12.0	12.5
25	200	69	11.0	12.75	.68	242	12.8	209	3.4	7.8	9.1
20	200	80	14.5	15.5	.75	217	10.4	203	1.8	6.4	6.9
15	200	58	23.0	25.0	.98	225	11.8	207	.7	4.0	4.3
10	200	46	51.0	55.0	2.73	220	17.3	204	1.4	1.9	1.97
8	100	Larvae all died before pupating.									
5	100	Larvae did not grow. All died before feeding.									

Thermal constant of curve: Mean, 217°, S. D., 11°; Ave. Min., 205.6°, S. D., 2.3°. Zero of curve: Mean, 6°; Ave. Min., 6°.

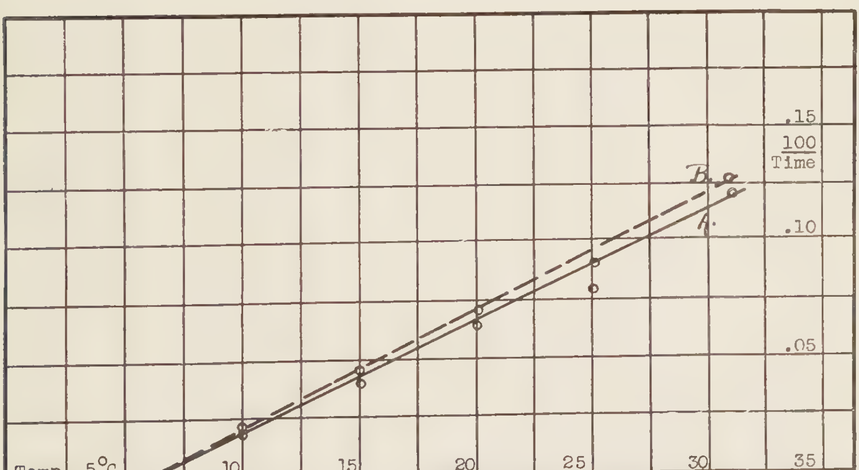


Fig. 11.—Velocity of development of Pontia rapae larvae. A.—Based upon the mean time of pupation. B.—Based upon the average time of first pupation for the different lots. (See Table 11).

TABLE 12.—Pontia rapae, pupae. Constant temperatures (See Fig. 12).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	100	43	5.0	5 35	.2	147°	5.5°	140.0°	2.1°	19.0	20.0
30	100	50	5.9	6 9	.61	159	14.0	135.7	3.2	14.5	16.9
25	100	64	7.6	8.5	.57	153	10.2	130.0	0	11.7	12 5
20	150	80	10.0	11.5	.54	150	7.1	130.0	.2	8.7	10.0
15	150	74	17.4	18 0	.82	144	6.6	139.2	.4	5.5	5.75
10	100	39	48.0	49.0	.98	147	9.0	144.0	0	2.0	2.1
5	75	0									

Thermal constant of curve: Mean, 150.1°, S. D., 8.2°; Ave. Min., 136.4°, S. D., 4.2°. Zero of curve: Mean, 7°; Ave. Min., 7.5°.

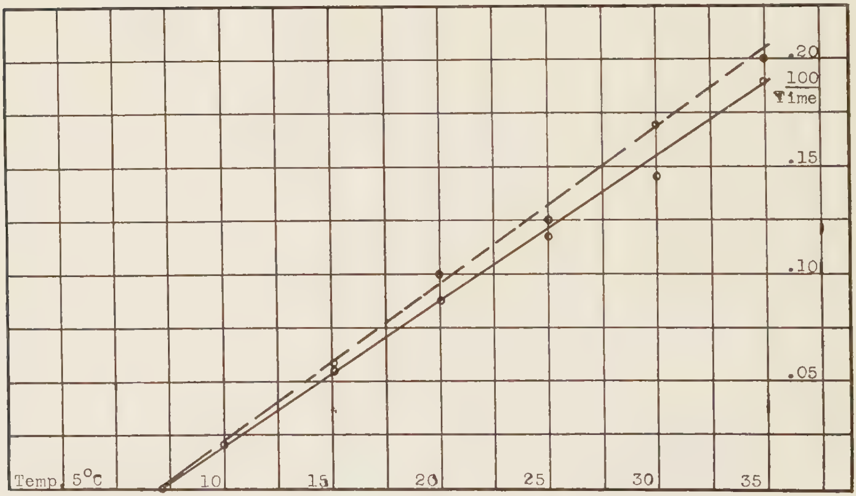


Fig. 12.—Velocity of development of Pontia rapae pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 12).

TABLE 13.—Malacosoma americana, pupae. Constant temperatures (See Fig. 13)

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	50	58	8.5	9.5	.33	239.2°	3.7°	233.7°	0°	10 5	11.7
30	100	42	10.5	11.3	.55	237.0	4.8	236.3	0	8 8	9 5
25	100	64	14.0	15.1	.62	248.0	10.2	245 0	0	6 5	7 1
20	100	70	18 8	22.5	.81	247.0	8.9	235.0	1.6	4.4	5 3
15	100	33	34.0	47.0	3.63	282.0	21.7	255.0	0	2.1	2.9
10	50	No emergence.									

Thermal constant of curve: Mean, 247°, S. D., 11.2°; Ave. Min., 239°, S. D., 7.4°. Zero of curve: Mean, 9°; Ave. Min., 7.5°.

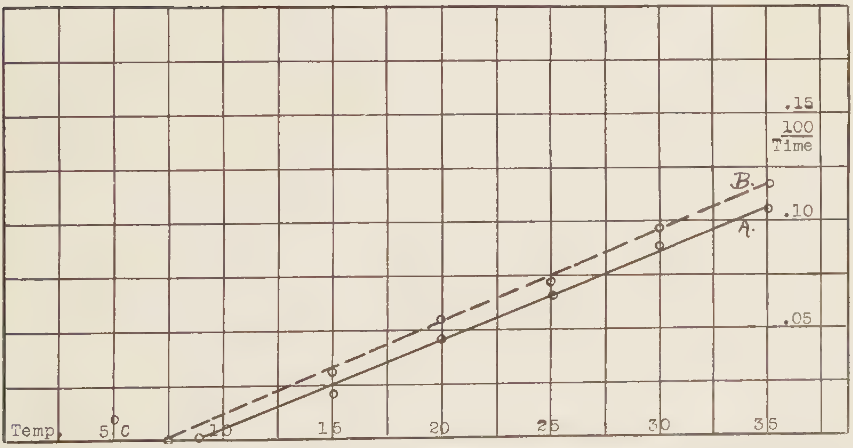


Fig. 13.—Velocity of development of Malacosoma americana pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 13).

TABLE 14.—Carpocapsa pomonella; pupae. Constant temperatures (See Fig. 14)

T.	No. of Insects	oped Perc't. Devel-	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	75	73	6.0	6.25	.54	162.5°	14.0°	159.0°		16 0	16 7
30	90	75	7.0	7.25	.37	152.7	8.5	150.5	1 3°	13 8	14 3
25	90	82	8.4	8.8	.44	140.8	7.0	138.3	2 1	11 4	11 9
20	100	78	12.2	13.3	.79	146.0	8.6	140 3	3 0	7 5	8 2
15	100	70	22.0	26.0	1.12	156.0	11.3	143 0	4 2	3 8	4 5
12	50	36	44.0	51.0	2.19	153.0	6.6	154.0	0	2 0	2 3

Thermal constant of curve: Mean, 150°, S. D., 8.9°; Ave. Min., 145.6°, S. D., 7.8°. Zero of curve: Mean, 9°; Ave. Min., 8.5°.

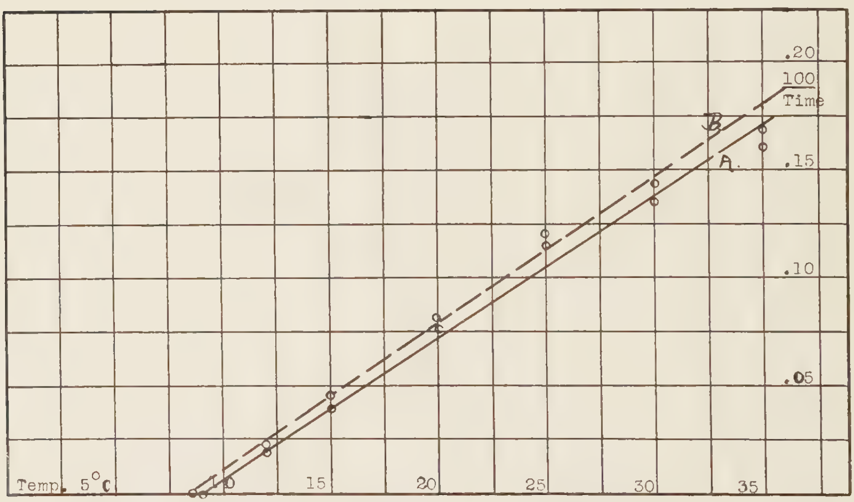


Fig. 14.—Velocity of development of Carpocapsa pomonella pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 14).

TABLE 15.—Leptinotarsa 10-lineata; eggs. Constant temperatures (See Fig. 15).

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
32 2°	200	74	3 8	3 0	.08	78.6°	2 1°	73.3°		33.0	35.0
25	300	68	4 0	4 1	.12	77.9	2 3	76 0		24.0	25.0
20	240	82	5 4	5 9	.29	82.6	4.9	75.4	.9°	17.0	18.5
15	240	48	8 5	8 9	.26	80.1	3 2	76 5	.76	11.2	11.8
10	180	25	20 0	21.0	.69	84.0	2.8	80.0	.69	4.8	5.0
5	200	None hatched.									

Thermal constant of curve: Mean, 79°, S. D., 2.9°; Ave. Min., 76.8°, S. D., .29°. Zero of curve: Mean, 6°; Ave. Min., 6°.

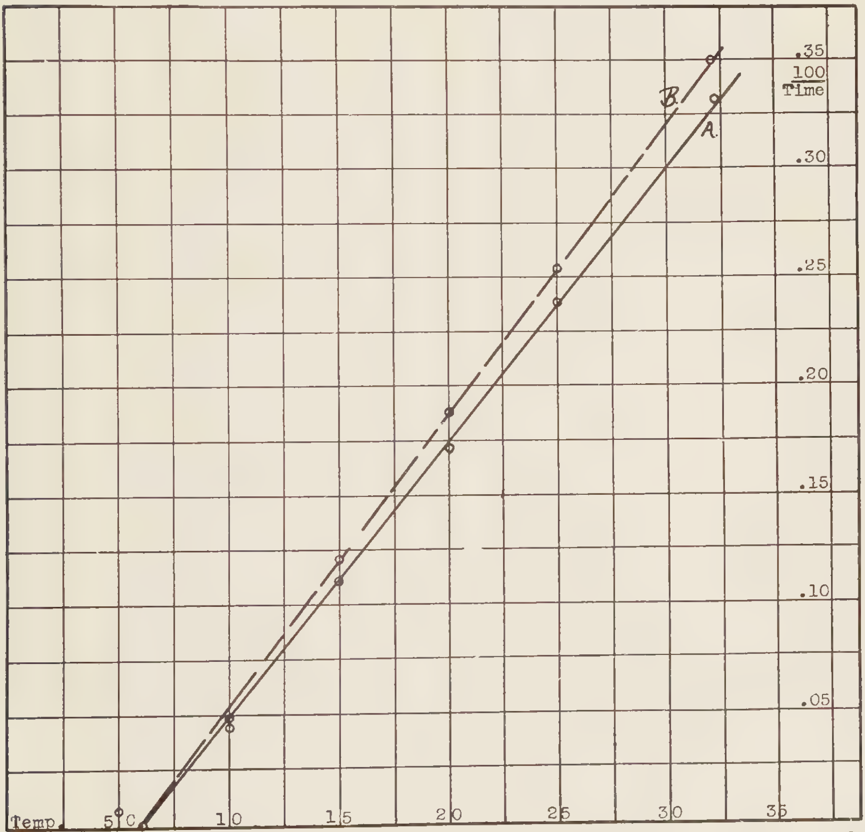


Fig. 15.—Velocity of development of Leptinotarsa 10-lineata eggs. A.—Based upon the mean time of hatching. B.—Based upon the average time of first hatching for the different lots. (See Table 15.)

TABLE 16.—Leptinotarsa 10-lineata, larvae. Constant temperatures (See Fig. 16)

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	200	Only four pupated.									
30	200	52	7.8	9.5	.81	237°	20.0°	188.8°	4.7°	10.5	12.8
25	250	60	10 0	11.75	.73	235	14.6	192.0	......	8.5	10.0
20	250	71	13.3	15.0	.56	225	9.9	188.9	2.6	6.7	7.5
15	240	67	20.0	20.25	.96	202	18.2	184.0	.7	4.8	5.0
10	250	38	45.5	46 5	2.8	232	13.9	191.1	1.1	2.2	2.2

Thermal constant of curve: Mean, 230°, S. D., 12.6°; Ave. Min., 189.6°, S. D., 8°. Zero of curve: Mean, 5°; Ave. Min., 5.8°.

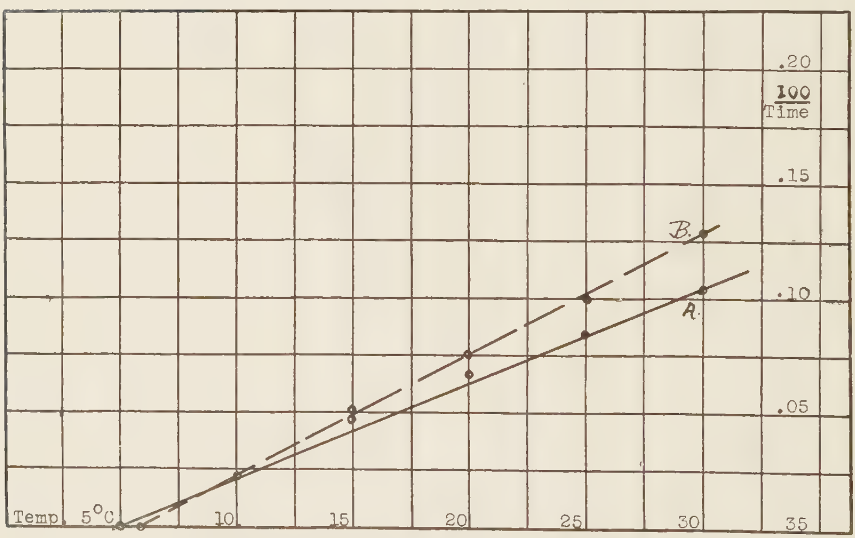


Fig. 16.—Velocity of development of Leptinotarsa 10-lineate larvae. A.—Based upon the mean time of pupation. B.—Based upon the average time of first pupation for the different lots. (See Table 16.)

TABLE 17.—Leptinotarsa 10-lineata, pupae. Constant temperatures (See Fig. 17)

T.	No. of Insects	Perc't. Devel-oped	Length of Stage in Days			Acc. Effect. Temp.				Index of Dev.	
			Ave. Min.	Mean	S. D.	Mean	S. D.	Min.	S. D.	Mean	Min.
35°	75	14	4.5	4.5		123.7°		123.7°		22 0	22.0
30	100	47	4 5	4.8	.22	108.0	4.9°	101.2		21 7	22 0
25	100	61	5 5	6 25	.13	109.4	2 2	96.2		16 0	18 1
20	100	70	8 0	8.6	.24	107.5	3.0	100.0		11.6	12 5
15	95	78	13 5	14.0	.42	105.0	3.2	101.2		7 1	7 4
10	100	40	46.0	50.0	2.37	125.0	6.0	115.0		2 0	2.2

Thermal constant of curve: Mean, 109.9°, S. D., 3.6°; Ave. Min., 102.6°, S. D., 1.4°. Zero of curve: Mean, 7.5°; Min. Ave., 7.5°.

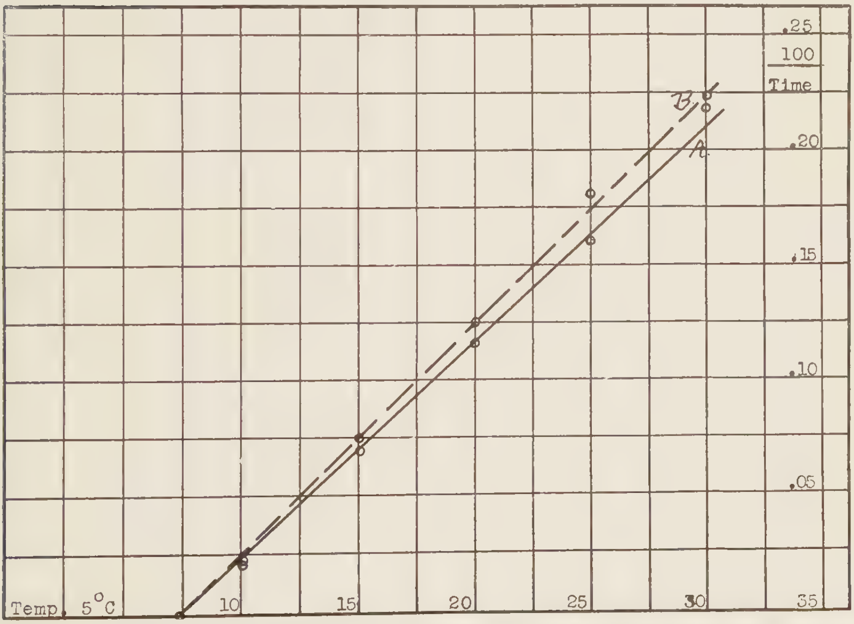


Fig. 17.—Velocity of development of Leptinotarsa 10-lineate pupae. A.—Based upon the mean time of emergence. B.—Based upon the average time of first emergence for the different lots. (See Table 17.)

THE THRESHOLD OF DEVELOPMENT

If it is true that there is, at temperatures sufficiently low, a definite cessation of development there must be some point at which the developmental processes no longer operate or at which development, arrested by low temperatures, again begins to manifest itself when temperatures are gradually raised.

The determination of the location of this point, or threshold of development, has been the object of a supplementary series of experiments. It was found that development did not occur, or did not continue to completion, at temperatures, in the constant temperature series, which approached to within one to five degrees of the zero point of the velocity curves. Observations of larvae showed that they would usually feed and grow to some extent, for a few days, at temperatures often within one degree of the zero of the velocity curve.

No perceptible growth of newly hatched larvae and no feeding of such larvae could ever be detected at this zero point although well grown larvae, transferred from higher temperatures, apparently fed to a slight extent but accomplished no preceptible growth. Young larvae, at the zero point, usually died within a few hours; older larvae lived for a more or less indefinite period, possibly as long as a month, but no perceptible growth ever occurred.

At one or two degrees above this zero point larvae, ready to pupate, transferred from warm incubators, would sometimes pupate. Larvae, therefore, showed some developmental activity at temperatures close to the zero of the velocity curve. The lack of evidence of development at that point was taken to indicate that it could not be much above the actual threshold while evidence of some development almost at the zero indicated that it was not below the threshold. Since developmental processes were never completed at these temperatures, the time factor could not be measured to determine whether it would coincide with the point indicated by the velocity curve.

Development of pupae, when incomplete, is not evidenced by any external change. Internal changes are of such a nature in the early period of pupal development as to afford little evidence of slight development. Experiments designed to determine possible development of pupae at temperatures down to the zero of the velocity curves were arranged, based upon the assumption that some development might be possible at low temperatures even though complete transformation was not. These experiments con-

sisted of placing different lots of pupae in low temperature incubators for periods and transferring them to warmer temperatures to complete their development.

It was thought that if measurable development had taken place at the low temperature it should have manifested itself in the reduction of the time necessary to complete the transformation at the higher temperature. In these tests a factor which apparently affects some of the results in the constant temperature series is again of importance. This is an apparent loss of vitality incident to the prolonged vital period, possibly connected with the expenditure of energy represented by the basal metabolism indicated in the carbon dioxide tests, and a change in the physical condition of the pupal covering which seems to be in the nature of a ripening which possibly renders escape from the puparium, by the fully developed fly, more than normally difficult. These possible factors are discussed in connection with the constant temperature series on pages 13 and 14.

TABLE 18.—Development of pupae of L. caesar kept first in cold temperature incubators at near the zero of the curve of velocity of development (6° to 6.5°) and removed, after varying periods, to incubator at 20°.

No. of Insects	Days at 6-6.5°	Acc. Temp.	Days at 20° (Minimum)	Acc. Temp.	Total Acc. Temp.	Excess Over 122.8°
200	30°	0°	9 4	127°	127°	4.2°
100	60	0	9 3	126	126	3.2
200	90	0	9 4	127	127	4.2
200	130	0	9 6	129 6	129 6	6 8
200	180	0	10	135	135	12 2
200	235	0	10 5	142	142	19.2
200	272	0	10 4	141	141	18 2
140	335	0	11	148 5	148 5	25.7
200	366	0	11 5	155	155	32.2
200	418	0	12	162	162	39.2
200	480	0	12 5	168.7	168.7	45.9
200	540	0	12	162	162	39.2
300	611	0	15	202 5	202.5	79.2
300	654	0	13	175 5	175 5	52.7
284	691	0	14	189	189	66.2

Thermal constant for the insect as indicated by the velocity curve—122.8°, S. D. 9.2°, based on mean emergence.

Emergence varied from less than 1 to 31 per cent in all lots in the cold conditions longer than 90 days. Two individuals emerged from the last lot. All were deformed in some manner and were unable to fly.

A second similar series with the blowfly gave results as shown in Table 19. Accidental warming of the cold storage chamber spoiled this material so the test was abandoned.

Tables 18 and 19 indicate that there is no development accomplished at the temperatures equivalent to those indicated as zero

TABLE 19.—Pupae of blowfly in incubator at the zero indicated by the velocity curve, 6.5° to 7°; transferred to the 20° incubator.

No. of Insects	Days at 6, 5-7°	Days at 20° (Minimum)	Effect. Temp. Accumulated	Excess Over 130.1°
100	30	10.3	133.9°	3.8°
200	90	12	156.	25.9
200	180	12.6	164.	33.9

Thermal constant indicated by the velocity curve 130.1°, S. D., 5.7°.

TABLE 20.—Development of pupae of the blowfly incubated first at 8° then at 20°.

No. of Pupae	Days at 8°	Acc. Effect. Temp. at 8°	Days at 20°	Acc. Effect. Temp. at 20°	Total Effect. Temp.	Apparent Effective Temp. at 8°
200	42	42°	7.2	93.6°	135.6°	36.5°
200	60	60	5.8	75.4	135.4	54 7
200	70	70	5.2	67.6	137.6	62 5
200	80	80	5.3	68.9	148 9	61.2
200	90	90	5.0	65.0	145.0	65 0
200	120	120	6.0	78.0	198.0	52 0
200	150	150	7.8	101.4	251.4	59 7

Zero of velocity curve, 7°; Thermal constant indicated by curve, 130.1°, S. D., 5.7.

TABLE 21.—Development of pupae of Lucilia caesar kept first at 7° and later transferred to 20° incubator.

No. of Pupae	Days at 7°	Acc. Effect. Temp. at 7°	Days at 20°	Acc. Effect. Temp. at 20°	Total Effect. Temp.	Apparent Effective Temp. at 7°
500	15	7.5°	8.2	106.7°	114.2°	18 6°
500	30	15.0	8.4	109.4	124 4	13.4
500	60	30.0	7.8	101.3	131.3	21.5
500	90	45.0	9.0	121.5	166.5	1.3
500	120	60.0	8 7	113.0	173 0	9.8

Zero of velocity curve 6.5°; Thermal constant indicated by curve 122.8°, S. D., 9.2°.

TABLE 22.—Development of tent-caterpillar pupae incubated first at 10° then transferred to 20° incubator.

No. of Pupae	Days at 10°	Acc. Effect. Temp. at 10°	Days at 20°	Acc. Effect. Temp. at 20°	Total Effect. Temp.	Apparent Effective Temp. at 10°
20	30	30°	21	231°	261°	16°
20	45	45	21	231	276	16
20	75	75	20	220	295	25
20	120	120	22	242	362	5

Zero of velocity curve 9°; Thermal constant indicated by the curve 247°, S. D., 11.2°.

TABLE 23.—Development of pupae of the blowfly incubated first at 20° and then transferred to incubator at 8°.

No. of Pupae	Days at 20°	Acc. Effect. Temp. at 20°	Days at 8°	Acc. Effect. Temp. at 8°	Total Effect. Temp.	Apparent Effective Temp. at 8°
100	8	104°	23	23°	127°	26.1°
100	7	91	46	46	137	39.1
100	6	78	No emergence after 90 days when observations were discontinued.			

Zero indicated by velocity curve 7°; Thermal constant 130.1°; S. D., 5.7°.

points by the curves of velocity of development, or that any development which may take place is not sufficient to overcome the effect of the retardation incident to the undue prolongation of the developmental stage.

It is, of course, possible that slight development may have taken place at these or even at lower temperatures, but escaped observation.

Tables 20 to 23, inclusive, show, on the other hand, that there is perceptible development at temperatures from one-half degree to one degree above the zero indicated by the velocity curve. In one or two cases this development is slightly greater than was to have been expected if the zero of the curve represents the true threshold of development. (See Lot 1, Table 21, and Lot 1, Table 23). Usually the influence of the low temperature exposures is rather less than their time would indicate. Generally, when the time was not prolonged to more than about 60 days, the departure from the thermal constant was but little, if any, greater than the deviation from the constant temperature data.

Variable Temperatures

To determine any possible effect arising from the mere fact of variation in temperatures, and to determine also whether temperature summations based on ordinary outdoor conditions are comparable to those based on constant temperatures, two series of experiments were conducted. The one was merely the recording of the time of development of insects under outdoor conditions, the temperature being measured with a thermograph and the thermal increment, calculated from the zero of the constant temperature velocity curves, compared with that derived from equivalent constant temperature conditions. The second series consisted of a shifting of material from one constant temperature incubator to others, so as to get an effect comparable to a daily variation which might occur outside and a comparison of the data secured

from this, with the outdoor series and with constant temperature series. This should show whether any variation noted in the behavior of the insects reared outdoors is due to the variation in temperature or to some unrecognized factor.

TABLE 24.—Development of insects under outdoor conditions. Accumulated temperatures above zero of the velocity curves measured from thermograph charts with a planimeter.

Insect	Stage	Zero of Curves	Therm. Const.	Mean Temp.	Time Days	Accumulated Temp.	Calculated Time at Constant Temp. (Days)	Variation from Therm. Const.	
								Plus	Minus
L. caesar	pupae	6 5°	122.8°	21.2°	8.2	120.5°	8.35		2.3°
L. caesar	larvae	5 5	110.7	20.9	6.4	98.6	7.2		12.1
C. vomitoria	pupae	7.0	130.1	21.2	8.4	120.3	9.2		9.8
C. vomitoria	larvae	6.0	104.7	20.5	6.6	94.7	7.2		10 0
L. 10-lineata	egg	6.0	70 0	20.4	5.1	73.4	5.5		5.6

TABLE 25.—Development of blowfly at different constant temperatures. Temperature constant at one point for one or more days then changed to a different constant for the remainder of the period of development.

First Temp.	Time at First T. (Days)	Second Temp.	Time at Second T. (Days)	Accum. Temp.	Variation from Constant	
					Plus	Minus
30°	2	10°	14.8	107.2°	2.5°	
20	2	10	18.25	101.0		3.7°
10	2	30	4.3	111.2	6.5	
10	2	20	6.7	101.8		2.9
35	1	15	8.3	103.7		1.0
40	1	15	7.1	97.9		6.8
15	7	40	1.5	114.0	9.3	

Zero of velocity curve, 6°. Thermal constant of curve, 104.7°.

Table 24 shows an apparent acceleration of development under outdoor conditions over that observed at constant temperature of the same value. This acceleration is slight in extent, at its greatest being little more than the variation encountered in different lots at constant temperatures. The data, however, represent several groups of insects, not less than 1,000 individuals in each test, and the nature of the variation was consistent, never being in the plus direction but always in the minus, not only in the average shown in the table but also among the individual lots. It seems safe to conclude that there is some acceleration which may be attributed to outdoor conditions as compared with incubator conditions.

Lehenbauer (1914) in his work with maize seedlings found that the rate of growth showed a decrease when the temperature was kept at a constant value. This is further evidence for the conclusion that constant temperatures may present an abnormal and, therefore, detrimental, environment for some organisms.

TABLE 26.—Development of blowfly larvae at temperatures changed at six or twelve hour intervals; the temperature for each six-hour period being indicated.

Temperatures				Mean	Time Days	Acc. Temp.	Variation from Thermal Const.
1	2	3	4				
20°	25°	20°	15°	20°	6 6	92.4°	—12 3°
10	20	30	20	20	6.8	95.2	— 9 5
10	30	30	10	20	7.0	98 0	— 6 7
5	25	25	25	20	6.8	95.2	— 9 5
15	25	25	15	20	6.9	96.6	— 8.1
15	25	35	25	25	5.35	101.6	— 3.1
20	25	30	25	25	5.5	104.5	— 2

Zero of velocity curve, 6°. Thermal constant of curve, 104.7 , S. D., 6.9°.

TABLE 27.—Development of blowfly pupae at temperatures changed at six or twelve hour intervals; the temperature for each six-hour period being indicated.

Temperatures				Mean	Time Days	Accum. Temp.	Variation from Thermal Const.
1	2	3	4				
20°	25°	20°	15°	20°	9	117°	—13.1°
10	20	30	20	20	8.9	115.6	—14.5
10	30	30	10	20	9.2	119.6	—10 5
15	25	25	15	20	9	117	—13.1
10	15	40	15	20	9.5	123.5	— 6.6
15	25	35	25	20	6.8	122.4	— 7.7
20	25	30	25	25	7	126.	— 4.1
10	20	10	20	15	15.8	126.4	— 3.7

Zero of the velocity curve, 7°. Thermal constant of curve, 130.1°, S. D., 5.7°.

Tables 26 and 27 show a similar acceleration when temperature variations were provided within the constant temperature incubators by moving the insects from one to another. Here again the variation is not usually greater than the deviation from the constant temperatures but it is without exception a minus variation. The significant fact about the variation in these tables is similar to that observed under the outdoor conditions; that is, that the variation from the calculated thermal constant is always a minus variation.

Table 25 gives the results from a series where the temperature was changed only once during the course of development, being kept for a period at one constant temperature and after one or more days changed to another constant and allowed to remain at that point until development was completed.

The variations from the thermal constant of the velocity curve are slight, within the standard deviation and occur in both the plus direction and the minus direction. They indicate no stimulating, or other, effect produced by a single change of temperature during

the developmental period so it seems that variation, to cause acceleration, must be daily in its occurrence or at least must occur with relative frequency.

Why a stimulation should occur from variation in temperature is not clear. A speculative reason might be that the protoplasm of these organisms is adapted to variable conditions and that variable tempertures constitute a normal environment while constant temperatures are abnormal and so retard development. This would interpret the difference in rate as a retardation due to constant temperatures rather than as an effect of the stimulation from variation of the temperature.

It is reasonable to conclude that the acceleration resulting from outdoor conditions as compared with constant temperatures within the incubators is due to the fact of variation rather than to any other change in the conditions and it follows that computations from field observations will have to consider a thermal constant somewhat lower than one which may be established from constant temperatures within the laboratory. The results here presented do not show sufficient uniformity to suggest any method for the correction of constant-temperature constants so that they may be applied to field temperatures.

The foregoing statements should not be taken to indicate that there are no field conditions other than variations in temperature which may influence the rate of development.

Carbon Dioxide Production at Different Temperatures

The theory of the thermal constant suggests the idea that development may represent a constant *quantity* of metabolism. If this is true, it would be natural to expect that other indices of the quantity of metabolism should show some approach to a constant. Krogh (1914 and 1916) has reported some work which indicates a relatively constant total carbon dioxide production during a given developmental period. The work here reported was undertaken therefore, to throw additional light upon the problem of the constant quantitative relations of development.

CARBON DIOXIDE ESTIMATION

Special apparatus used in the estimation of the carbon dioxide production of insects was simple. At first it was thought necessary to make the absorption of the carbon dioxide continuous. It was later found that no apparent difference in results was caused if the carbon dioxide was removed from the breeding tubes only once daily and this practice was adopted. For this work tubes about two

inches by six inches were used as containers. These were open at both ends and were stoppered with rubber stoppers perforated for drainage tubes. The drainage tubes were connected through the walls of the incubators with the container for the absorption of the gas. Once each day a stream of carbon dioxide-free air was passed through the tubes and the carbon dioxide contained in the tubes carried with the air through an absorbing solution containing sodium hydroxide of standard strength to an indicator solution of sodium phosphate and phenol-sulphone-phthalein. The amount of carbon dioxide was calculated, at the end of the test, by a comparison of the indicator solution with standard solutions of known acidity. These were made by adding known quantities of hydrochloric acid to the standard indicator solution. Color comparison was relied upon to determine the degree of change.

While this method cannot pretend to absolute accuracy it is probably as reliable for the small quantities of carbon dioxide involved as any other available method. It is probable that the errors in the different tests were of the same order of magnitude and not great enough to invalidate such tentative conclusions as have been drawn from this phase of the work.

Weighed lots each containing 40 grams of pupae of the blowfly, about 500 individuals being included in each lot, were used in this study. Those lots of insects kept at the lower temperatures failed to complete their development by the end of 62 days and so were discarded, examination subsequently showing that they were nearly all dead. Table 28 summarizes the results.

TABLE 28.—Calliphora vomitoria pupae. Zero of velocity curve 7° to 7.3°.

Tempt.	No. of Lots	Total Grams CO_2	Time in Days	Average per Day
30°	16	2 5946	6	4324
20	15	2 7022	9.7	2785
10	12	2 8910	49	0590
8	4	1 3224	62	.0213 Discontinued
7	4	3869	62	.0062 Discontinued
5	2	.1440	62	0008 Discontinued

The three lots at the lower temperatures, since they were discontinued before development was complete, and since many pupae were dead before the experiments were discontinued show merely that metabolism was going on at these temperatures and indicate that it was more rapid at 8° than it was at 7° or 5°. Since it was not known how many of the pupae were dead in each lot at different stages of the experiment, the latter conclusion is not established

beyond doubt as it is entirely possible that large numbers of survivors at the higher of these temperatures explain the differences in quantity.

The carbon dioxide production at the three higher temperatures is shown to be nearly the same in amount. The percentage of emergence was approximately the same in the three lots or series. There is shown, in the results, a slightly greater production total at low temperatures than at high. This may easily be due to experimental error since neither the method nor its application pretends to absolute accuracy. There is, however, another explanation which, while not established, may be suggested. The results show that carbon dioxide was produced at temperatures below those at which development has been apparent in any of the other experimental work. This indicates a certain amount of respiration concerned not with development but with the mere maintenance of life. This may be ascribed to basal metabolism. It is reasonable to assume that this basal metabolism continues within the range of developmental temperatures. It is also possible to assume that it becomes progressively greater with increased temperatures, although there is no evidence offered here which will completely support that assumption.

If we assume the basal metabolism to persist through the range of temperatures where development is possible, regardless of whether it decreases or increases, we may find a possible explanation of at least a part of the discrepancy noted in the total carbon dioxide production at the different temperatures. The observed amounts may represent a constant total developmental metabolism plus a more or less constant daily basal metabolism repeated for the number of days which were required for development. Assuming the production at 7°, 0.0062 grams daily, to represent basal metabolism for any temperature, we have then to subtract 0.0062 times 6 days from the 30° total; 0.0062 times 9.7 days from the 20° total and 0.0062 times 49 days from the 10° total. If this be done we have for the corrected total representing development only; at 30°, 2.5574 grams; at 20°, 2.6421 grams; and at 10°, 2.5872 grams, which brings the value of the totals as near to a constant as could be expected from the method used.

Whether this treatment of the data is justifiable or not must be proven by subsequent investigation. In any event the carbon dioxide production totals at the three temperatures are decidedly of the same order of magnitude and offer no difficulty in the way

of the acceptance of the thermal constant as indicating that the processes of development represent a definite total of metabolic activity which may require a definite amount of heat for its accomplishment.

Attempts were made, early in the study of the carbon dioxide production, to make comparisons on the basis of daily production at different temperatures. This was found to be impossible because the production, at any one temperature, is not the same day after day but varies widely according to the internal condition of the pupae. This fact has been well established by other investigators; Tangl (1909), Krogh (1914 and 1916), Sosnowski (1902) and Weinland (1906) all mention it. It is necessary, therefore, in comparative work, to consider the entire developmental period or to compare a day at one temperature with the period of time at a second temperature which has been experimentally demonstrated to be equivalent to a day at the first temperature, basing comparisons on the amount of development accomplished during the period. It is necessary also that the same portions of the developmental period be compared with each other; that is, it would not be correct to compare a period representing the first one-fourth of the total period with another representing the second one-fourth.

While the results from the comparative daily measurements do not bear directly on the problem they may be included here since they serve to illustrate the point just made.

TABLE 29.—Carbon dioxide production of pupae of C. vomitoria by days. Average in grams CO_2 for three lots of 40 grams each at each temperature.

Day	Production at 30°	Production at 20°
1st	.5062	.2043
2nd	.4694	.2969
3rd	.2045	.3756
4th	.1920	.3406
5th	.4642	.3025
6th	.5501	.2962
7th		.2128
8th		.1440
9th		.1606
10th		.1682
Totals	2 3866	2.5216

The totals given in Table 29 do not represent quite the entire production as some of the pupae were discarded after the majority had emerged in each of the lots.

Moisture

The estimation of the effects which variations in moisture either in the atmosphere or in the soil surrounding the organisms or in their food has been no part of the purpose of this paper. That variation in atmospheric and other moisture may affect the rate of development or inhibit it entirely has been abundantly demonstrated.

A small series of moisture tests was made, not for the purpose of studying moisture relations in general—but merely to determine whether such variations in moisture as might occur in the experimental material used in temperature work could be expected to have any material importance in the interpretation of results. These constituted a comparison of high atmospheric moisture (80 per cent relative humidity or higher), with low moisture (30 per cent relative humidity or lower), at several temperatures and with several insects. The results are given in Table 30.

TABLE 30.—Development of insects under variable moisture conditions.

Insect	Stage	Temp.	High Moisture (80%)		Low Moisture (30%)	
			Time in Days	Per Cent Emerged	Time in Days	Per Cent Emerged
C. vomitoria	pupae	30°	6	81	5 85	23
C. vomitoria	pupae	20	9 2	88	9 35	46
C. vomitoria	pupae	15	16.8	78	19	39
L. Caesar	pupae	30	5.	64	5.25	47
L. Caesar	pupae	20	9.1	85	9.7	67
L. Caesar	pupae	15	14.5	74	14 75	62
S. Carnaria (?)	pupae	30	5.8	86	6.	69
S. Carnaria (?)	pupae	20	9.1	82	9.	71
S. Carnaria (?)	pupae	15	16.2	70	16 4	64
L. Caesar	larvae	30	4.6	67	4 7	60
L. Caesar	larvae	20	7.5	85	7.4	72
L. Caesar	larvae	15	12.1	78	12 3	71

Moisture conditions as extreme as those represented in Table 30 did not occur with any of the fly material studied. Variations indicated in the table are slight, no greater than may be found in the individual lots comprising any one of the averages given in the constant temperature tables. There is to be noted a decrease in percentage of emergence in the dry lots which is probably of significance. Likewise, in the dry lots at the higher temperature, and to a less extent at all temperatures, a reduction in the size of the emerging individuals was frequent as was also an increase in the percentage of imperfect flies.

These results merely indicate that the variations in atmospheric moisture had little effect under the conditions of these ex-

periments. Moisture conditions of the food of the larvae and of the soil surrounding the pupae were kept as near to the standard as possible, but the extremely rapid drying under the dry conditions caused some variation in the superficial layer of sand.

Elimination of consideration of moisture variations as an important factor seems to have been justified.

Sources of Error

Attempt has been made to reduce experimental error to a minimum in this work but it is still probable that small errors of various natures contribute to the variability of the results. Temperature has been controlled to within four-ninths of a degree C. plus or minus. It is still possible that the variation in some of the lots was consistently in one direction while in other lots it was in the reverse direction. Where the period was long, the error thus accumulated, even though it amounted to only one-fourth degree, would be great enough to account for nearly any of the variations which have been recorded. In a similar manner, a discrepancy of a fraction of a degree in the calibration of a thermometer or in the reading of it, would accumulate an error proportional to the length of the period involved. In the first instance the error would be always in one direction; in the second, if the reading were done by one person, the error would be likely to be in one direction.

Still another possible source of error based upon temperature records is the variation in temperature within the incubator. Every effort was made to have this temperature uniform within what were considered satisfactory limits and the records show that this was done. At the same time the possibility of a variation of not to exceed one-half degree which might well have been rather consistently in one direction, must be accepted and would further contribute to the general variability of the results.

The time factor introduces another source of error. Observations, as has been stated, were made at six hour intervals where the developmental period was expected to be less than twenty days and usually at similar intervals regardless of the length of the developmental period. Time of emergence or pupation was recorded as at the time of observation or as having taken place in the middle of the preceding six hour period, experience with the appearance of emerging or pupating individuals enabling one to tell with considerable certainty which record would most nearly approximate the actual conditions. Nevertheless, a possible maximum error up to six per cent must be admitted. This error will tend to have a greater value where the developmental period is short than where it is

long and will probably be more frequently in the plus direction than in the minus.

Variation in the material used would include possible seasonal variation, the work having been done at all seasons of the year when material was available; year to year variation, the summaries including, in the fly material, insects collected during at least five different years and the individual variation which occurs among the individuals of any lot originating from a single mass of eggs or from masses collected at any one time and place. Locality variations are eliminated because all material used was collected in one restricted locality, probably all within one hundred yards of one spot.

It is not to be supposed that the observational errors, or possibility of observational errors were disregarded; every precaution was taken to exclude them and it is certain that they were not more important, at the worst, than has been suggested above. In order that these unavoidable errors might be equalized, large numbers of individuals were used wherever that was possible so that small variations would tend to cancel each other and the general average represent as nearly as possible the true conditions.

Discussion of the Data

CONSTANT TEMPERATURE SERIES

In a previous paper, (Sanderson and Peairs, 1914), the writer concluded, independent of previous work, that the developmental curve was an hyperbola and its reciprocal, the curve showing relative velocity of development, was, in its ideal form, a straight line. From these conclusions it was assumed that the threshold of development (developmental zero was the name applied at that time) should, theoretically, be the zero of the velocity curve or the point at which that curve intersected the temperature axis. The data in this study have been collected largely for the purpose of determining whether the earlier conclusions were justified. An inspection of the graphs showing the velocity curves for the material of this study will show that the points on these curves at least approach the straight line condition. To show the closeness of this approach the summary in Table 31, based on the data from the fly material only, has been prepared. This shows the percentage of departure of points of all the curves, from the calculated straight line. Departures on the curves based on data from the other insects are somewhat greater but there is a similar distribution of plus and minus values.

TABLE 31.—Departure, expressed in percents, or points on the velocity curves, from the theoretical straight line curve.*

Temp.	Mean or First Em.	Table's Included (Numbers) 1	2	3	4	5	6	7	8	Average in Percent
35°	Mean	—1.6	—1.5	—6	—1.5	—1.6	— .6	—2 2	—1	2 12
	First	— .5	5.	—1 1	1 5	1.	1.8	1.6	4	1 6
30	Mean	—2 7	—3	9	2 8	2 5	2	1 2	4	1 7
	First	— .8	1 2	— .1	8	.2	1.2	.7	3.	1 0
25	Mean	—7.	—2.5	— .2	—3.	2.6	—6.	—2.2	—8.	3 9
	First	— .2	—1.	—2.	— .7	1.3	—3.	2.	— .8	1.15
20	Mean	—3.	2.0	—2.5	—5.	0.0	—5.	—4.	— .8	2 8
	First	—2.9	1.7	— .8	—1.6	—2.8	2 1	— .5	— .5	1 6
15	Mean	3.0	0 2	0.6	—4.	— .8	10.	7.	7.	4 05
	First	2.0	—3.0	2.2	.6	—1.6	2.	— .6	1.2	1 65
10	Mean	8.	10.	4.5	8.	—4.	—4.	10.	25.	9 2
	First	4.	4.	2.	4.	—8.	—2.	6.	11.	5 6
8	Mean	11.	25.	7.	24.	5.	13.			14
	First	.8	8.	3.5	—4.	8.	4.			8 1
Aver. for Table	Mean	5.3	6.3	3.4	6 9	2.36	5.5	4.6	7.6	5 25
	First	2.3	3.4	1.7	1.9	3.3	2.3	1.6	2.8	2 4

*Tested by Harris' method for determining goodness of fit, the formula being

$$X^2 = S \frac{(o-c)^2}{c},$$

where o is the observed value for the "constant" at any point, while c is the calculated value for the same point, the values for X^2 being converted into an expression of the chances favoring the straight line interpretation of the data, the values for the mean and for the minimum time emergence data from tables 1 to 8, give the following:

1	38-1	99-1
2	53-1	99-1
3	96-1	99-1
4	99-1	99-1
5	95-1	98-1
6	70-1	98-1
7	96-1	99-1
8	10-1	93-1

In practically all cases these values indicate a certainty that the straight line is the proper interpretation for the data. It is to be noted that the values indicate clearly that the use of the minimum emergence data is preferable.

Table 31 shows that there is a difference in the degree of error indicated in the mean curves and in the first emergence curves, the latter being consistently lower. There is also a difference in the distribution of the errors. The mean temperature summary shows that variations at high temperatures are all in the minus direction while those at the lower temperatures, 8° and 10°, are nearly all in the plus direction. The reason for the minus variation at 35° is probably that the low temperature plus variations are rather large and that these have shifted the position of the curve so that the true nature of the variations at 35° may have been obscured.

In the summary of first emergence data, on the other hand, the low temperature variations are seen to be much smaller so that they have had less effect in changing the position of the curve relative to the high temperature points; these latter now show a decided tendency to vary in the plus direction and this probably indicates

the beginning of the high temperature retardation effect. This high temperature retardation has not been emphasized in the data presented but has been generally noted. At points ranging from about 35°, more or less, the development is slowed down. Rarely is complete development possible at 40°. This fact has been brought out by other investigators (Krogh, 1914) and seems to be a general phenomenon.

No evidence which would tend to suggest an experimental explanation of this behavior has been offered. Probably the limits of what is termed normal development occur about this point on the temperature scale. The lethal effect of high temperatures, which may have to do with changes in the chemical condition of the protoplasm, possibly due to colloidal changes, may show here the first evidences of their action. For a limited range of temperature, development although retarded, is still complete. Somewhat higher temperatures still permit partial development but death intervenes before the process is complete. Such lethal effects may actually be present at lower temperatures but be too slight in extent to be noticeable.

Departures from the mean, indicated in Table 31, for median temperatures, particularly those based upon first emergences, are slight, usually well within the limits of observational error, and show a fairly even distribution between plus and minus aberrations.

The summary indicates that the averages based upon time of first emergence are probably a better expression of the temperature effect than are those based upon mean emergence.

The extent and nature of the variations from the constant indicated in the summary are the strongest evidence presented that the straight line is the true shape of the curve of velocity of development, at median temperatures. Near the lower end of the curves, a rather consistent variation in the plus direction, indicating retardation of development and a greater time requirement, is found. Even here, the daily value of such variations is extremely small; their considerable effect in the total thermal increment is due to the fact that they are repeated daily for a period of many days.

Explanation of this retardation may readily be found in the developmental conditions of both larvae and pupae. In the case of larvae, the necessity for changing the food material when the developmental period lasted much longer than it probably ever does under normal conditions outdoors, causes some delay incident to

the transfer of larvae from the old food to the new and to the fact that they do not begin feeding immediately upon new food. This might easily account for such retardation as has occurred with larvae.

Pupae, when their development requires a long period, regardless of the care with which temperature and moisture conditions are maintained, show a change in the texture of the outer covering or puparium. This may be likened to a ripening process or it may better be called merely aging. These puparia are tougher in their texture than the fresher ones which undoubtedly delays the emergence of at least the weaker individuals in a group and certainly prevents entirely the emergence of many of them, thus accounting for a part of the mortality always observed in low-temperature lots.

It is to be noted that these possible factors will both cause retardation in development; that is, variation in the plus direction, which is in accord with the observations. It is likewise probable that they will operate less noticeably with the more vigorous individuals in any lot so that the time of first emergence might be expected to be less influenced than the mean. This agrees with results also, the variations from the straight line being less marked when the curve is based upon first emergence than when it is based upon the mean emergence time.

The foregoing discussion applies only to evidence presented in this paper. So far as that evidence alone is concerned there is no reason to believe that the straight line interpretation might not apply to all parts of the curve below certain upper limits as has been previously pointed out.

A considerable amount of data from other sources indicates that the developmental process at low temperatures within a few degrees of the zero of the velocity curve, cannot be expressed by the continuation of the straight line but that there is a distinct aberration in the direction which indicates acceleration.

Shelford (1917) has called particular attention to this point and the work of Krogh (1914), Reibisch (1902), Loeb and Wasteneys (1911), Loeb and Northrup (1917), Headlee (1914), and Krafka (1920), to mention only a few of those bearing on this point, as well as a more recent study by Shelford (1926), have indicated clearly this deviation in the minus direction. In some cases this deviation has been so great that development has been demonstrated at temperatures below the zero of the velocity curve. This was shown by Loeb and Northrup (1917) as pointed out by

Krafka (1920). Shelford has found a similar condition with the codling moth while the work of Krogh suggests that the condition holds true for several animals studied by him.

In none of these instances is the variation great in degree but the fact that it has been observed by several different investigators working with diverse materials precludes any explanation on the basis of experimental error. The uniformity of the conclusions which these several investigations demonstrate, points strongly to a probability that the threshold of development is actually below the zero of the velocity curve.

Apparently the only contrary evidence is contained in this paper. Of the fact of retardation here recorded, there can be no doubt. Nor can there be doubt as to the evidence showing that there was no apparent development at the zero point even with flies kept at that temperature for periods extending as long as twenty-three months. The improbability of a fundamental difference, at this point, of the temperature effect on different organisms, leads to the search for an explanation which may reconcile the conflicting data.

It has already been pointed out that the retardation of developmental rate as compared with that to be expected from the straight line curve, might be explained by the operation of outside factors, variation in food supply of larvae, and change in the texture of the puparium, not connected directly with temperature. It is certainly possible that these same factors might account for the somewhat greater variation from the condition of the curve representing a lower threshold of development.

The lack of evidence of development at the zero point has been mentioned. Slight development at temperatures one degree or one-half degree above this zero has been recorded but this has always been less than the time at these temperatures would lead one to expect. This shows that there is a factor for retardation operating at low temperatures. It is conceivable that this retardation is so great at the next lower temperatures studied as entirely to obscure the evidence of any slight development which might take place.

It might be expected that the zero of the developmental curve would be the zero, or threshold, of development. Actually, it seems that it is not. A probable explanation is that development begins at a point somewhat lower than the zero of the curve; that it is at first very slow but gradually increases in rate of acceleration until the protoplasm reaches the condition of stability which it maintains through the normal range of development. From this point of

stability the curve of increase in velocity runs in a straight line until it reaches the point of falling-off near the upper limit of the developmental temperatures. This condition represents a gradual increase in the value of the day degree from zero, at the threshold, to a constant value at the point of stabilization of the protoplasm.

Discussions up to this point have dealt with the applicability of the theory of the interpretation which assumes the developmental curve to be an hyperbola and its reciprocal, the straight line, to represent the rate of increase in the velocity of development. Whether this is the best explanation of the facts must be determined by the consideration of other explanations which have been offered. Most prominent among these has been the law of van't Hoff.

The law of van't Hoff (1884) states that the velocity of a chemical reaction increases with the temperature and that the coefficient expressing the rate of increase is usually between two and three for each ten degree rise in temperature. Actually, over any considerable temperature interval, the coefficients show a much greater variation than this and it seems to have been no part of the assumption in the original formulation that the coefficient was, for any ten degree interval, the same as for any other ten degree interval.

Observations in the field of biology showed that the actual coefficient of increase in growth or rate of development was frequently between two and three and this led to the use of the van't Hoff formula as a convenient means for describing the rate of increase in terms which might refer the origin of the increased velocity to chemico-physical causes.

An examination of the coefficients for a chemical reaction and a comparison of these with similar coefficients for a biological reaction, will show that they are similar in order of magnitude; that they decrease with each successive rise in temperature; and that they show, graphically, the same relation to the straight line as do the developmental data. If, as is apparent, the van't Hoff coefficients are not constant they can have no value in other than a descriptive sense, correlating the biological process with the chemico-physical, unless a method for the calculation of the one from the other can be devised. The straight line interpretation of the velocity curve seems to furnish this.

It appears, therefore, that the van't Hoff coefficients as used in the description of the rate of chemical reactions, apply in a sense to biological processes, but that they vary in their magnitude and may best be calculated from the straight line index.

Krogh (1916) reaches conclusions essentially similar to the foregoing. Kanitz (1915) brings out the similarity between the biological coefficients and those for chemical reactions.

Arrhenius' modification of van't Hoff's formula has also been suggested as a possible basis for the explanation of the biological problem. It is open to the same objection as the van't Hoff formula in that the coefficients derived from its application are not ordinarily constant. As applied to data in this paper, the Arrhenius' coefficients plot graphically on an approach to the straight line index (van't Hoff coefficients plot graphically on the hyperbola).

Crozier (1924) has found that for certain reactions of organisms to stimuli as influenced by temperature changes, the Arrhenius' coefficient (termed "temperature characteristic" by Crozier) is a constant for a certain part of the temperature range, but that at a temperature of usually about 16°, the constant changes and another holds from that point downward. Crozier interprets this by assuming that the reaction is first based upon some one single chemical reaction of a simple nature; that at the point where the second coefficient enters a different reaction begins to take place. No parallel between these phenomena observed by Crozier and the developmental data is apparent. It is entirely probable that the vital reactions in development are affected by so many different chemical processes that we are not yet ready to attempt to isolate the effects of the individual ones. Krogh found the formula of Arrhenius to be no more satisfactory than that of van't Hoff in the explanation of data which was essentially similar to that contained herein.

Of both these formulae it may be said that they do not conflict with any of the conclusions involving the straight line interpretation of the velocity curve but that neither is as useful for study of biological data as is the study of such data in relation to the straight line.

The formula of van't Hoff is as follows:

$$Q10 = \frac{K_2}{K_1} \left[\frac{10}{t_2 - t_1} \right]$$

$Q10$ being the usual designation of the van't Hoff coefficient; K_1 being the time at the first temperature; t_1 and K_2 the time at the second temperature.

Arrhenius' formula is usually given as:

$$K_2 = K_1 \, . \, e \, \frac{q}{r} \, . \, \frac{T_2 - T_1}{T_2 \cdot T_1}$$

In this formula K designates the time factors at the first temperature and at the second; T refers to absolute temperature and "r" is a constant which is approximately equal to two and is usually applied as that number; "q" is then the constant for the formula or the "characteristic" according to the usage of Crozier.

For biological reactions it might be better to use effective temperatures rather than absolute temperatures since, according to the evidence, temperatures below the threshold have no influence upon development. Figure 18 shows the Arrhenius' coefficients based upon the minimum emergence data from Table 4, in their relation to the straight line. Figure 19 shows that van't Hoff coefficients from the same data and their relation to the curve.

Other suggested explanations of the velocity curve are somewhat indefinite. That the curve, near its lower limits, may be an exponential one, as has been suggested, now seems probable. That the straight line curve may be, in fact, not one curve but two, one representing development above a given point and another development below, or one representing the action of one set of forces and the other the operation of a different set of forces, the two being assumed to overlap and the straight line being the component of the two sets of forces, is within the bounds of speculation. Since there is no definite evidence upon which to base a discussion of this possibility no use can yet be made of it.

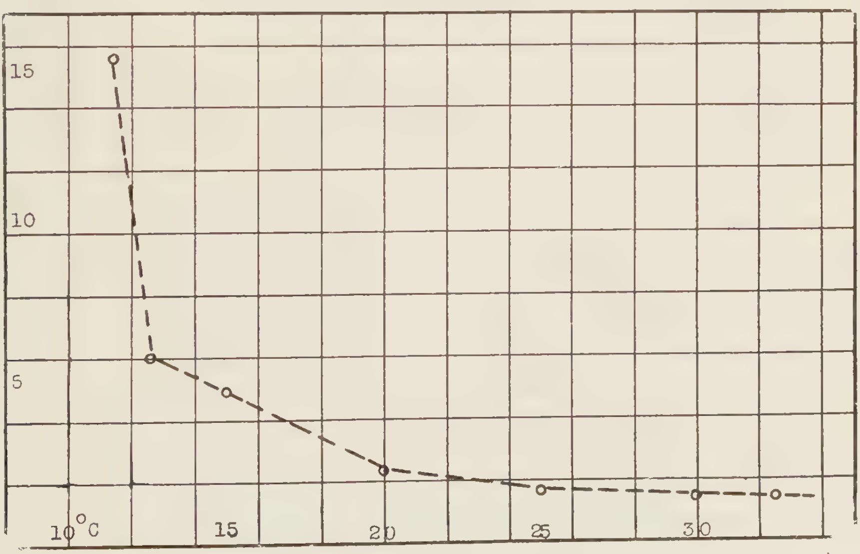


Fig. 18.—Arrhenius' coefficient based upon data in Table 4. (Effective temperatures.)

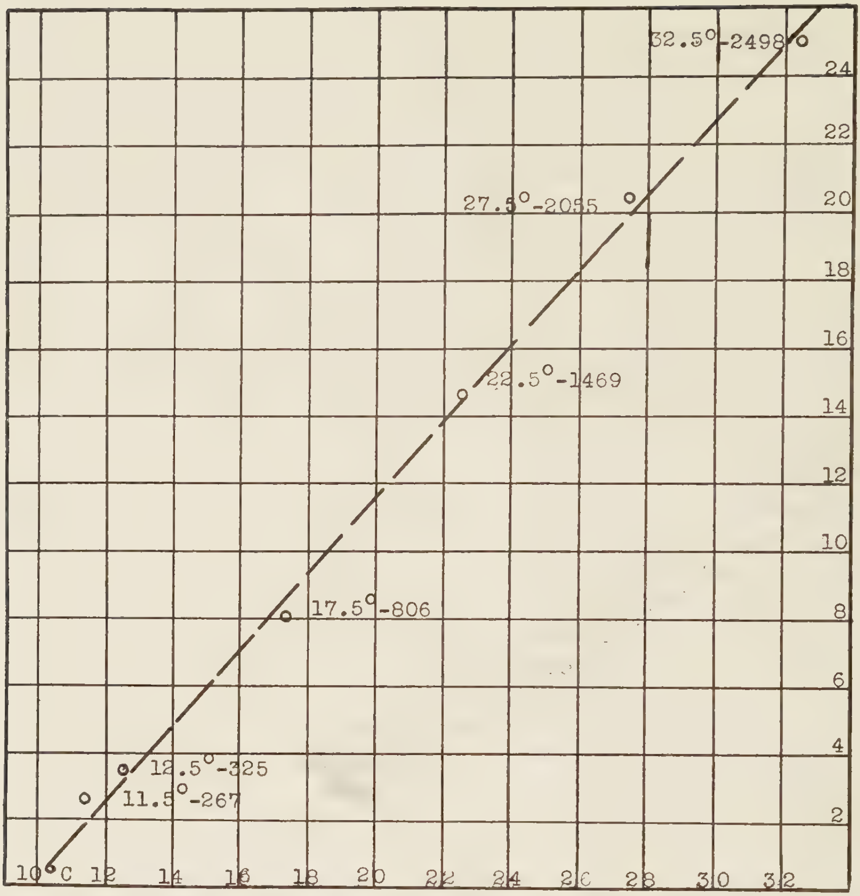


Fig 19.—Van't Hoff coefficients from data in Table 5. Based on minimum emergence records.

Still another possibility is that there is no definite law governing developmental processes. This is entirely contrary to the modern trend of interpretations of vital phenomena and absolutely untenable if we accept the principle of the essential unity of biological processes with those of chemistry and physics. Barry (1904) has pointed out that there is nothing more exact than the laws of thermodynamics and also the probability that these laws apply in biology. The whole trend of investigational results establishes this. If the data now available do not fit exactly any physical explanation it is entirely probable that the correct explanation has not been suggested or that the data are not sufficient in quantity or in accuracy.

SUMMARY

1.—It has been shown that the rate of development of certain insects is directly affected by the degree of temperature and that, for the greater part of the range of temperatures permitting development, this relation is best expressed by a curve for the velocity of development which takes the form of a straight line.

2.—Data indicate that the straight line departs from its course near the ends. At the upper end the departure is in the direction which indicates a slowing up of acceleration of development. The opposite condition is observed at the lower end of the curve but here, in the light of evidence presented by other investigators, it seems probable that the increase in the rate of acceleration is due to factors other than temperature and that the actual temperature effect would be represented by a departure from the straight line in the direction which would represent decrease in the rate of acceleration of development.

3.—For all points along the straight line part of the velocity curve, a given accumulation of temperature, or thermal increment, expressed in day-degrees, will accomplish a constant effect, expressed in growth or development. And, further, that summations of temperatures, to derive the constant, may be made from the zero of the velocity curve.

4.—The point at which development ceases is near to, but somewhat lower than the zero of the velocity curve. No definite method of locating this threshold of development, is suggested.

5.—Evidence of development, in the work reported here, has been lacking from insects reared at temperatures approximating the zero of the velocity curve but other investigators, working with other material, have found evidence of development at points even below the zero of the curve.

6.—Development has been found to be accelerated by variations in the daily temperature when compared with constant temperatures of the same apparent value.

7.—Some evidence is offered to indicate that the quality of carbon dioxide produced during a developmental period is near a constant, regardless of the temperature at which development takes place, and it is suggested that the departures from the constant may represent basal metabolism not directly associated with developmental processes.

8.—Data is presented which show that temperatures undergoing a daily variation similar to the normal variation found under outdoor conditions have a greater effect upon rate of development than do constant temperatures from which the same thermal increment is to be computed.

9.—It is shown in the discussions that the law of van't Hoff and possibly Arrhenius' formula also may be applied to developmental data but that the graphic interpretation, based upon the straight line curve, furnishes a more convenient method of analysis.

BIBLIOGRAPHY

ABBE, CLEVELAND
1878. THERMAL CONSTANT FOR LOCUST EGGS. First Report of the U. S. Ent. Comm. p. 426-432.

——— 1905. THE RELATION BETWEEN CLIMATE AND CROPS. U. S. Weather Bureau, Bul. 36.

APPLEMAN, C. O.
1923. FORECASTING THE DATE AND DURATION OF THE BEST CANNING STAGE FOR SWEETCORN. Md. Agr. Expt. Sta. Bul. 254.

ARRHENIUS, SVANTE.
1889. ZEITSCHR. PHYSIK. CHEM. 4.

BACHMETJEW, P.
1901. EXPERIMENTELLE ENTOMOLIGISCHE STUDIEN, I. TEMEPRATUR VERHALTNISSE BEI INSEKTEN. pp. 160. Leipzig, 1901.

——— 1907. EXPERIMENTELLE ENTOMOLOGISCHE STUDIEN VOM PHYSIKALLISCH-CHEMISCHEN STANDPUNKT AUS. Sofia.

BACK, E. A., and PEMBERTON, C. E.
1916. THE EFFECT OF COLD-STORAGE TEMPERATURES ON PUPAE OF THE MEDITERRANEAN FRUIT-FLY. Jour. Agr. Res. 6: 251-260.

BAILEY, L. H.
1896. THE SURVIVAL OF THE UNLIKE. New York.

——— 1889. THE INFLUENCE OF CERTAIN CONDITIONS ON THE SPROUTING OF SEEDS. Cornell Agr. Expt. Sta. Bul. 7.

BARENNE, DUSSER DE and BURGER, G. C. E.
1924. OXYGEN CONSUMPTION AND CARBON DIOXIDE OUTPUT. Jour. Phys. 59: 17-29.

BARRY, FREDERICK
1914. THE INFLUENCE OF TEMPERATURE UPON CHEMICAL REACTIONS. Am. Jour. Bot. 1: 203-225.

BAYLISS, W. M.
1924. PRINCIPLES OF GENERAL PHYSIOLOGY. London.

BERTRAND, G., BROCQ-ROUSSEN, ET DASSONVILLE.
1919. INFLUENCE DE LA TEMPERATURE ET D'AUTRES AGENTS PHYSIQUES SUR LE POUVOIR DE LA CHLOROPICRINE. Compt. Rent. Acad. Sci. 159: 1059-1061.

BEAUVAIS
1837. SEIDENWURMER.—ISIS VON OKEN. p. 781 (Cited from Backmetjew.)

BODINE, JOSEPH HALL
1921. FACTORS INFLUENCING THE WATER CONTENT AND THE RATE OF METABOLISM IN CERTAIN ORTHOPTERA.. Jour. Expt. Zool. 32: 137-164.

——— 1925. THE EFFECT OF TEMPERATURE ON THE RATE OF EMBRYONIC DEVELOPMENT OF CERTAIN ORTHOPTERA. Jour. Exp. Zool. 42: No. 1.

CANDOLLE, A. P. DE
1855. GEOGRAPHIQUE BOTANIQUE RAISONEE. Paris.

——— 1865. DE LA GERMINATION SOUS LES DEGRES DIVERS DE TEMPERATURE CONSTANCE. Bibl. univ. et Revue suisse. Tome 14: 243-282. Geneva.

COTTON, E. C., AND VOORHEES, J. F.
1911. THE CATTLE TICK AS AFFECTED BY CLIMATE. Tenn. Agr. Expt. Sta. Bul. 94.

CROZIER, W. J.
1924. BIOLOGICAL OXIDATION AS A FUNCTION OF TEMPERATURE. Jour. Gen. Phys. 7: 189-216.

——— 1924.—CRITICAL THERMAL INCREMENTS FOR THE MOVEMENT OF A DIPLOPOD. Jour. Gen. Phys. 7: 123-216.

———, AND STEIR, T. B.
1924. CRITICAL THERMAL INCREMENTS FOR RHYTHYMIC RESPIRATORY MOVEMENTS OF INSECTS. Jour. Gen. Phys. 7: 429-447.

———, AND FREDRIGHT, H.
1924. CRITICAL THERMAL INCREMENTS FOR MOVEMENTS OF OSCILLATORIA. Jour. Gen. Phys. 7:143-151.

——— PHOTOTROPIC CIRCUS MOVEMENTS OF LIMAX AS INFLUENCED BY TEBPERATURE. Jour. Gen. Phys. 7: 151-170.

DANNEVIG, HAROLD
1894. THE INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF THE EGGS OF FISHES. 13th Ann. Rept. Fisheries Board of Scotland. p. 147-153.

DAVENPORT, C. B.
1897 and 1899. EXPERIMENTAL MORPHOLOGY (Parts First and Second). New York.

DEAN, G. A.
1911. HEAT AS A MEANS OF CONTROLLING MILL INSECTS. Jour. Ec. Ent. 4: 143-158.

EDWARDS, C. L.
1902. PHYSIOLOGICAL ZERO AND THE INDEX OF DEVELOPMENT OF THE EGG OF THE DOMESTIC FOWL. Am. Jour. Physiol. 6: 351-397.

EDWARDS AND COLIN
1834. INFLUENCE DE LA TEMPERATURE SUR LA GERMINATION. Ab. Sec. Nat. 2nd. Series I.

FABRE, J. H.
SOUVENIRS ENTOMOLOGIQUES. Troisieme Serie.

FERE, C.
1894. NOTE SUR L'INFLUENCE DE LA TEMPERATURE SUR L'INCUBATION DE L'OEUF DE POULE. Jour. de l'Anat. et de la Physiol. 30: 352-365.

√ GLENN, P. A.
1922. CODLING MOTH INVESTIGATIONS. Nat. Hist. Surv. of Ill. 14: 219-288.

GREEN, SETH
1870. TROUT CULTURE, Rochester, N. Y.

HARTZELL, F. Z.
1919. COMPARISON OF METHODS FOR THE COMPUTATION OF DAILY MEAN TEMPERATURES: EFFECT OF DISCREPANCIES UPON THE INVESTIGATIONS OF CLIMATOLOGISTS AND BIOLOGISTS. N. Y. Agr. Expt. Sta. Bul. 68 (Tech).

HEADLEE, T. J.
1914. THE EFFECTS OF TEMPERATURE AND MOISTURE ON THE RATE OF INSECT METABOLISM. Jour. Econ. Ent. 7: 413-417.

——— 1917. SOME FACTS RELATIVE TO THE INFLUENCE OF ATMOSPHERIC HUMIDITY ON INSECT METABOLISM. Jour. Econ. Ent. 10: 31-38.

HERMS, WM. B.
1907. AN ECOLOGICAL AND EXPERIMENTAL STUDY OF SARCOPHAGIDAE. Jour. Exp. Zool. IV: 45-83.

HEARSH, A. H.
1923. THE EFFECT OF TEMPERATURE UPON THE BAR-EYED RACE OF DROSOPHILA. Jour. Biol. Chem. 59: 55-73.

HERSH, ROSELLE KARRAR
1923. THE EFFECT OF TEMPERATURE UPON THE FULL-EYED RACE OF DROSOPHILA. Jour. Biol. Chem. 59: 43:55.

HENDERSON, L. J.
1913. THE FITNESS OF THE ENVIRONMENT. New York.

HERWIG, O.
1896. UEBER DEN EINFLUSS VERSCHEIDENER TEMPERATUREN AUF DIE ENTWICKLUNG DER FROSCHEIER. Sitzungsber. Berlin. Akad. Bd. 19.

——— 1898. UEBER DEN EINFLUSS DER TEMPERATURE AUF DIE ENTWICKLUNG VON RANA FUSCA UND R. ESCULENTA. Arch. f. Mikr. Anat. 51: 319-381.

HILDERBRANDT, F. MERRILL
1917. A PHYSIOLOGICAL STUDY OF THE CLIMATIC CONDITIONS OF MARYLAND AS MEASURED BY THE RATE OF PLANT GROWTH. Physiol. Res. 2: 341-405.

HOFF, J. H. VAN'T
1884. ETUDES DE DYNAMIQUE CHIMIQUE. Amsterdam.

HOFFMAN, J.
1881. COMPARATIVE PHENOLOGICAL CHART FOR CENTRAL EUROPE. Petermann's Geog. Mitth.

HOGE, M. A.
1915. THE INFLUENCE OF TEMPERATURE UPON THE DEVELOPMENT OF A MENDELIAN CHARACTER. Jour. Expt. Zool. 18: 241-286.

HOPKINS, A. D.
1900. HESSIAN FLY IN WEST VIRGINIA. W. Va. Agr. Expt. Sta. Bul. 67: 242-243.

——— 1918. GUIDES TO AGRICULTURAL RESEARCH. Monthly Weather Review, U. S. Dept. Agr. Suppl. 9: 1-41.

———— 1919. THE BIOCLIMATIC LAW. Sci. Monthly. 8: 496-513.

HOWARD, L. O.
1896. SOME TEMPETATURE EFFECTS ON HOUSEHOLD INSECTS. U. S. Dept. Agr. Div. Ent. Bul. 6, n.s. p. 13-17.

HUNTER, S. J. and GLENN, P. A.
1909. THE GREEN BUG AND ITS NATURAL ENEMIES. Univ. of Kans. Bul. 9: 165-200.

HUNTER, W. D.
1908. A TENTATIVE LAW RELATING TO THE INCUBATION OF THE EGGS OF THE CATTLE TICK. Jour. Econ. Ent. 1: 51-55.

————, and HINDS, W. E.
1904. THE MEXICAN COTTON BOLL WEEVIL. U. S. Dept. Agr. Bur. of Ent. Bul. 45.

————, and HOOKER, W. A.
1907. THE NORTH AMERICAN FEVER TICK. U. S. Dept. Agr. Bur. of Ent. Bul. 72.

HUNTINGTON, E.
1915. CIVILIZATION AND CLIMATE. New Haven.

JOHNSON, EARL S.
1923. MOISTURE RELATIONS OF PEACH BUDS DURING WINTER AND SPRING. Md. Agr. Expt. Sta. Bul 255.

JOHANNSEN, A. C., and KROGH, A.
1914. THE INFLUENCE OF TEMPERATURE AND CERTAIN OTHER TACTORS ON THE GROWTH OF FISHES. Conseil Int. p. l'exploration de la mer. Publ. de circ. No. 68, Copenhagen.

KANITZ, ARISTIDES
1915. TEMPERATURE UND LEBENSVORGANGE. Berlin.

KING, HELEN DEAN
1910. TEMPERATURE AS A FACTOR IN THE DETERMINATION OF SEX. Biol. Bul. 18: 131-137.

———— 1903. EFFECT OF HEAT ON THE DEVELOPMENT OF TOAD EGGS. Biol. Bul 5: 218-232.

KNIGHT, HARRY H.
1924. ON THE NATURE OF THE COLOR PATTERNS IN HETEROPTERA WITH DATA ON THE EFFECTS PRODUCED BY TEMPERATURE AND HUMIDITY. Ann. Ent. Soc. of Am. 17: 258-274.

KNOWLTON, HARRY E.
1922. STUDIES IN POLLEN WITH SPECIAL REFERENCE TO LONGEVITY. Cornell Agr. Expt. Sta. Memoir 52.

KNOWLTON, FRANK P., and STARLING, E. H.
1912. INFLUENCE OF TEMPERATURE ON THE ISOLATED MAMMALIAN HEART. Jour. Physiol. 44: 206-219.

KOPEC, STEFAN
1924. STUDIES ON THE INFLUENCE OF INANITION ON THE DEVELOPMENT AND DURATION OF LIFE IN INSECTS. Biol. Bul. 46: 1-23.

KRAFKA, JOSEPH, JR.
1920. THE EFFECT OF TEMPERATURE UPON THE FACET-NUMBER IN THE BAR-EYED MUTANT OF DROSOPHILA. Jour. Gen. Physiol. 2: 409-464.

KRAMER, S. D.
1915. EFFECT OF TEMPERATURE UPON THE LIFE CYCLE OF MUSCA DOMESTICA AND CULEX PIPIENS. Science, N. S. 41: 874-877.

KROGH, AUGUST
1914. ON THE RATE OF DEVELOPMENT AND CARBON DIOXIDE PRODUCTION OF CHRYSALIDES OF TENEBRIO MOLITOR AT DIFFERENT TEMPERATURES. Zeitschr. fur allgem. Physiol. 16: 178-190.

——— 1916. THE RESPIRATORY EXCHANGE OF MAN AND ANIMALS London.

LARSON, A. O., and SIMMONS, PEREZ
1923. NOTES ON THE BIOLOGY OF THE FOUR-SPOTTED BEAN WEEVIL, BRUCHUS QUADRIMACULATUS FABR. Jour. Agr. Res. 22: 609-616.

LEHENBAUER, P. A.
1914. THE GROWTH OF MAIZE SEEDLINGS IN RELATION TO TEMPERATURE. Physiol. Res. 1: 247-288.

LEPESCHKIN, S.
1912. LETHAL EFFECTS OF TEMPERATURE ON PLANT TISSUES. Bericht de, Deutsches Bot. Ges. 30.

LILLIE, R. F. and KNOWLTON, F. P.
1897. OF THE EFFECT OF TEMPERATURE UPON THE DEVELOPMENT OF ANIMALS. Zool. Bul. 1: 179-193.

LINSSER, CARL
1867. DIE PERIODISCHEN ERSCHEINUNGEN DES PFLANZEN-LEBENS IN IHREN VERHALTNISSE ZU DEN WARME-ERSCHEINUNG. Meb. Acad. Imp. St. Petersburg, (7) T. 11.

——— 1869. UNTERSUCHUNGEN UEBER DIE PERIODISCHEN LEBENS-ERSCHEINUNGEN DER PFLANZEN. Zweite Abhandlungen. Mem. Acad. Imp. St. Petersburg, (7) T. 13.

LIVINGSTONE, B. E.
1916. PHYSIOLOGICAL TEMPERATURE INDICES FOR THE STUDY OF PLANT GROWTH IN RELATION TO CLIMATIC CONDITIONS Physiol. Res. 1: 399-420.

———, and LIVINGSTON, GRACE J.
1913. TEMPERATURE COEFFICIENTS IN PLANT GEOGRAPHY AND CLIMATOLOGY. Bot. Gaz. 56: 349-376.

LOEB, JACQUES
1906. THE DYNAMICS OF LIVING MATTER. New York.

———, and NORTHRUP, J. H.
1917. ON THE INFLUENCE OF FOOD AND TEMPERATURE UPON THE DURATION OF LIFE. Jour. Biol-Chem. 32: 103-121.

———, and WASTENEYS, H.
1911. ARE THE OXIDATIVE PROCESSES INDEPENDANT VARIABLES IN VITAL PROCESSES. Biochem. Zr. 36: 345-356.

———— INFLUENCE OF BASES IN THE DEVELOPMENTAL AND OXIDATIVE PROCESSES. Biochem. Zr. 37: 410-423. (Trans. titles).

McLean, F. T.
1917. A PRELIMINARY STUDY OF CLIMATIC CONDITIONS IN MARYLAND AS RELATED TO PLANT GROWTH. Physiol. Res. 2: 129-208.

McDougall, D. T.
1907. FACTORS AFFECTING THE SEASONAL ACTIVITIES OF PLANTS. Plant World, 10: 217-237.

————
1914. AUTO-THERMAL INTEGRATIONS OF TEMPERATURE COMPLEXES. Am. Jour. Bot. 1: 186-193.

Mellor, J. W.
1904. CHEMICAL STATICS AND DYNAMICS. Chap. 12. London.

Merreim, C. Hart
1894. LAWS OF TEMPERATURE CONTROL OF THE GEOGRAPHIC DISTRIBUTION OF TERRESTRIAL ANIMALS AND PLANTS. Nat. Geog. Mag. 6: 228-238.

Morgan, T. H.
1907. EXPERIMENTAL ZOOLOGY. New York.

Morgulis, S.
1924. EFFECTS OF ENVIRONMENTAL TEMPERATURE ON METABOLISM. Am. Jour. Phys. 71: 49-59.

Nernst, Walter
1895. THEORETICAL CHEMISTRY. Chap. 4. (Translation by Palmer) London.

√Peairs, L. M.
1914. THE RELATION OF TEMPERATURE TO INSECT DEVELOPMENT. Jour. Ec. Ent. 7: 174-179.

√ Pierce, W. Dwight
1916. A NEW INTERPRETATION OF THE RELATIONSHIPS OF TEMPERATURE AND HUMIDITY TO INSECT DEVELOPMENT. Jour. Agr. Res. 5: 1183-1191.

Plough, Harry H.
1917. THE EFFECT OF TEMPERATURE UPON CROSSING-OVER IN DROSOPHILA. Jour. Expt. Zool. 24: 147-209.

————
1921. FURTHER STUDIES ON THE EFFECT OF TEMPERATURE ON CROSSING-OVER. Jour. Expt. Zool. 32: 187-201.

Price, H. L.
1910. THE APPLICATION OF METEOROLOGICAL DATA IN THE STUDY OF PHYSIOLOGICAL CONSTANTS. Ann. Rept. Virginia Agr. Expt. Sta. for 1909-1910.

Putter, August
1914. TEMPERATURKOEFFIZIENTEN. Zeitschr. for Allgem. Physiol. 16: 574-627.

QUETELET, A.
1849. SUR LE CLIMAT DE LA BELGIQUE. Phenomenes periodiques des Plants. Chap. 4. Annales de l'Observatoire. Bruxelles.

REAUMUR, R. A. F. DE
1735. MEMOIRS, ACAD. DES SCIENCE, p. 545. Paris.

REIBISCH, J.
1902. UEBER DEN EINFLUSS DER TEMPERATURE AUF DIE ENTWICKLUNG VON FISCHEIERN. Wissenchaft. Meeresuntersuch., N. F., Abt. Kiel, 6: 215-231.

√ RICHARDSON, CHAS. H.
1925. THE OVIPOSITION RESPONSE OF INSECTS. U. S. Dept. Agr. Bul. 1324.

ROBERTS, ELMER
1918. FLUCTUATIONS IN A RECESSIVE MENDELIAN CHARACTER AND SELECTION. Jour. Expt. Zool. 27: 157-177.

ROGERS, CHAS. G.
1911. STUDIES UPON THE TEMPERATURE COEFFICIENT OF THE RATE OF HEART BEAT IN CERTAIN LIVING ANIMALS. Am. Jour. Physiol. 28: 81-93.

√ SANDERSON, E. DWIGHT
1908. THE INFLUCNCE OF TEMPERATURE IN THE NORTHERN DISTRIBUTION OF INSECTS. Jour. Econ. Ent. 1: 245-262.

——— 1908. THE RELATION OT TEMPERATURE TO THE HIBERNATION OF INSECTS. Jour. Econ. Ent. 1: 56-65.

——— 1910. THE RELATION OF TEMPERATURE TO THE GROWTH OF INSECTS. Jour. Econ. Ent. 3: 133-140.

SANDERSON, E. DWIGHT, and PEAIRS, L. M.
1914. THE RELATION OF TEMPERATURE TO THE DEVELOPMENT OF INSECTS. N. Hamp. Agr. Expt. Sta. Tech. Bul. 7.

SCHWETALLA, ALPHONSE M.
1924. INFLUENCE OF TEMPERATURE ON RATE OF LOCOMOTION OF AMOEBA. Jour. Morph. 39: 465-514.

SEVERIN, H. H. P. and SEVERIN, H. C.
1910. THE EFFECT OF MOISTURE AND DARKNESS ON THE EMERGENCE FROM THE EGG OF THE WALKING-STICK, DIAPHEROMERA FEMORATA, Say. Jour. Econ. Ent. 3: 479-481.

SHELFORD, V. E.
1917. PHYSIOLOGICAL PROBLEMS IN THE LIFE-HISTORIES OF ANIMALS WITH PARTICULAR REFERENCE TO THEIR SEASONAL APPEARANCE. Am. Nat. 52: 129-154.

——— 1920. PHYSIOLOGICAL LIFE HISTORIES OF TERRESTRIAL ANIMALS AND MODERN METHODS OF REPRESENTING CLIMATE. Illinois Acad. of Science. 13: 257-271.

———— 1926. AN EXPERIMENTAL INVESTIGATION OF THE RELATION OF THE CODLING MOTH TO WEATHER AND CLIMATE. Ill. Nat. Hist. Survey. Bul. 16, art. 5.

SNYDER, CHAS. D.
1907. DER TEMERATUR KOEFFICIENT DER GESCHWINDIGKEIT DER NERVENLEITUNG. Arch. Anat. und Phys.-Physiol. Abt. Jahl. 1907: 113-145.

———— 1908. A COMPARATIVE STUDY OF THE TEMPERATURE COEFFICIENTS OF VARIOUS PHYSIOLOGICAL ACTIONS. Am. Jour. Physiol. 22: 309-334.

———— 1911. ON THE MEANING OF THE VARIATION IN THE MAGNITUDE OF THE TEMPERATURE COEFFICIENT OF PHYSIOLOGICAL PROCESSES. Am. Jour. Physiol. 28: 167-175.

STEVENS, NEIL E.
1917. INFLUENCE OF CLIMATIC FACTORS ON THE DEVELOPMENT OF ENDOTHIA PARASITICA. Am. Jour. Bot. 4: 1-32.

———— 1917. INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF ENDOTHIA PARASITICA. Am. Jour. Bot. 4: 111-118.

———— 1917. TEMPERATURES OF THE CRANBERRY REGIONS OF THE UNITED STATES IN RELATION TO THE GROWTH OF CERTAIN FUNGI. Jour. Agr. Res. 11: 521-529.

SEYSTER, E. W.
1919. EYE-FACET NUMBER AS INFLUENCED BY TEMPERATURE IN BAR-EYED MUTANTS OF DROSOPHIA. Biol. Bul. 37: 168-182.

SHREVE, FORREST
1914. THE ROLE OF WINTER TEMPERATURES IN DETERMINING THE DISTRIBUTION OF PLANTS. Am. Jour. Bot. 1: 194-202.

SUMMERS, FRANCIS B.
1915. SOME STUDIES OF ENVIRONMENTAL INFLUENCE ON HEREDITY. Jour. Expt. Zool. 18.

TANGL, F.
1909. ZUR KENTNISS DES STOFF UND ENERGIEUMSATZES HOLOMETABOLER INSEKTEN WAHREND DER METAMORPHOSE. Pflugers Archiv. 13-: 1-55.

THOMAS, CYRUS
1879. RELATION OF TEMPERATURE TO THE DEVELOPMENT OF (LOCUST) EGGS. Second. Ann. Rept. U. S. Ent. Comm. Chap. 5.

TOTHILL, JOHN D.
1913. A STUDY OF THE VARIATION IN THE NORTH AMERICAN GREENBOTTLE FLIES. Ann. Ent. Soc. Am. VI: 241-256.

TOWER, W. L.
1912. MODIFICATION OF THE GERMINAL CONSTITUTION OF ORGANISMS. Heredity and Eugenics, Chap. 7.

———— 1918. THE MECHANISM OF EVOLUTION IN LEPTINOTARSA. Publication of the Carnegie Institute.

——— Von Oettingen, A. J.
1879. Phanologie der Dorpater Lignosen. Archiv fur die Naturkunde Liv-, Ehst- und Kurlands. Zweite Serie. pp. 241-352. Bande VIII. Dritte Lieferung. Dorpat.

Verworn, Max
1899. General physiology. (Trans. by F. S. Lee) London.

Wallich, Claudius
1900. Dept. U. S. Fish. Comm. for 1900, Pt. 26. House Documents 122, 56th Congress.

Waugh, F. A.
1898. A contribution to the knowledge of physiological constants. Ann. Rept. Vt. Agr. Expt. Sta. for 1897-98: 263-272.

Warder, R. B.
1881. In Am. Chem. Jour. 3: 203.

Weinland, E.
1906. Puppen von Calliphora. Ziet. 4. Biol. 48, 87-140. Muenschen u. Berlin.

Zeleny, Charles
1920. In Jour. Expt. Zool. 30: 293:324.

——— 1920. Tabulation of factorial values. Am. Nat. 54: 358-362.

——— 1922. In Genetics 7: 1-115.

Bulletin 209 November, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. GIDDINGS, Acting Director
Morgantown

Dusting vs. Spraying in the Apple Orchard

By
N. J. GIDDINGS
ANTHONY BERG and E. C. SHERWOOD

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr., ... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY (Includes Genetics)

R. J. Garber, Ph. D. — Agronomist
E. P. Deatrick, Ph. D. — Associate Agronomist (Soils)
T. E. Odland, Ph. D. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist (Soils)
D. R. Dodd, M. S. — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
J. H. Longwell, M. S. — Assistant Animal Husbandman
J. H. Rietz, D. V. M. — Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
L. P. Hansen, Ph. D. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
Paul Daughenbaugh — Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
G. Malcolm Trout, M. S. — Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
L. E. Dills, M. S.** — Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, Jr., M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M. — Home Economist
Hazel C. Cameron, M. S. — Research Specialist in Foods
Nell Nesbitt, A. M. — Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D. — Associate Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
H. P. Sevy, M. S. Agr. — Assistant in Horticulture
M. B. Hoffman, M. S. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman
E. T. Wightman, M. S. Agr. — Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D. — Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D. — Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*Dusting vs. Spraying in the Apple Orchard**

The experimental work discussed in this bulletin was begun in 1913 in cooperation with the Department of Entmology.† Tests with dust for control of peach diseases gave evidence of so much greater practical value than did the work with apples that special attention was given to this phase of the problem and the results for the years 1914 to 1917, inclusive, were published as Bulletin 167 of this Station. Since that time the experiments with dust have been continued in commercial apple orchards.

It was hoped that some combination of materials, equipment, and methods would be developed by means of which effective control of apple diseases with dust would be secured, and which would be of practical use to the fruit grower.

The results of the work have been made available to the fruit growers of the state from year to year by means of papers and discussions at the meetings of the State Horticultural Society and through the Extension Specialist in Plant Pathology. The present publication summarizes the work with apples to date.

In 1913 the apples were all killed by late freezes in two orchards where dusting and spraying experiments were undertaken. The orchards used during 1914 and 1915 were remarkably free from fungous diseases, except rust and black rot, and there was practically no evidence of control of these. In 1916 there were no experiments conducted with apples, but the work was again taken up in 1917, under conditions which gave promise of more definite disease control data.

In each of the experiments described in this bulletin, every reasonable effort was made to see that the trees were thoroughly coated with dust. The work was usually done in the early morning when the air was quiet and the foliage was still wet with dew, but some dust applications were made in the evening. Applications of dust were not made in the middle of the day because there was usually a breeze which would seriously interfere and it seemed desirable to have the material moistened by dew as soon as possible after applying. Early

---

*Submitted for publication April, 1926.

†As the dust materials appeared to give satisfactory insect control, the Department of Entomology discontinued active cooperation on this project, after the 1917 season. Professor L. M. Peairs and Mr. W. E. Rumsey assisted in the work and secured data on insect control previous to the 1918 season.

morning applications, while the leaves were still moist, seemed most satisfactory. In all of the later work, the trees were dusted from both sides.

EXPERIMENTS IN 1917

The experiments in 1917 were conducted on 11-year old Rome trees in the J. H. Stewart orchard at Raymond City. The equipment consisted of a large Niagara power duster and a Bean power sprayer. The materials used were 90-10 sulphur-arsenate dust, a copper-lime dust containing one part commercial Bordeaux powder (11% copper)

TABLE 1.—The effectiveness of certain treatments in preventing diseases and insect injuries on apple fruits. Fruit harvested September 21 to October 2, 1917.

Treatment	Fruit Picked or Dropped	Fruits Affected by Sooty Blotch		Fruits Affected by Scab		Total Fruit Examined*			Culls†	
		Number	Percent	Number	Percent	Number	Bushels	Fruits Per Bu.	Number	Percent
Dust Sulphur (90-10)	Picked	2918	99.7	2881	98.7	2924	12.0	244	305	10
Dust Sulphur (90-10)	Dropped	575	100.0	573	99.7	575				
Lime Sulphur Spray	Picked	2203	99.6	2086	94.5	2211	10.5	211	136	6.2
Lime Sulphur Spray	Dropped	1010	99.6	976	96.3	1014				
Untreated	Picked	1429	100.0	1416	99.1	1429	5.0	286	105	7.0
Untreated	Dropped	1167	100.0	1163	99.7	1167				
Bordeaux Spray	Picked	1696	99.7	963	56.6	1701	11.0	155	6	0.4
Bordeaux Spray	Dropped	292	99.7	225	76.7	293				
Bordeaux Dust	Picked	1807	100.0	1791	99.1	1807	8.0	226	61	3.4
Bordeaux Dust	Dropped	1181	100.0	1157	97.9	1181				
Untreated	Picked	978	100.0	976	99.8	978	3.6	270	112	12.5
Untreated	Dropped	322	100.0	319	99.1	322				

*The column headed, "Fruits per bushel", gives a very good idea of the relative size of the apples.

†Fruit was not sorted into grades but any which was considered as absolutely unmarketable was placed in culls.

to two parts lime, 3-5-50 Bordeaux spray, and 1-40 lime-sulphur spray. The pink or cluster bud application was omitted.

Applications were made as follows:

May 9, all materials (calyx spray)
July 16, all materials*

The amount of dust used per tree, per application, was about two-thirds pound of the sulphur-arsenate and one-third pound of the copper-lime.

The fruit showed practically a hundred percent infection of both scab and sooty blotch. There was no evidence of sooty blotch control by any of the materials used, and the only evidence of scab control was by the Bordeaux spray. The amount of insect injury was not sufficient to be of much importance, but there was no indication of control by any of the materials used.

In the three columns under "total fruit" of Table 1, there is some very interesting evidence as to the effect of treatments upon sizes of fruit. It required only 155 average apples from the Bordeaux sprayed plot to make a bushel while from the adjoining check plot it required 286 apples to make a bushel. It is believed that this difference in size was largely due to control of black rot leaf spot, and scab infections upon the leaves. No detailed leaf data were secured, but it was observed that the check plots lost their foliage first and the Bordeaux sprayed plot retained its foliage longest.

EXPERIMENTS IN 1918

The trees in the 1918 experiments were of the Rome variety and twelve years old in the J. H. Stewart orchard at Raymond City. The equipment consisted of a large Niagara power duster and a Bean power sprayer. The materials used were 90-10 sulphur-arsenate dust, 3-5-50 Bordeaux mixture, and dry lime-sulphur used at the rate of 3 pounds to 50 gallons of water.

Applications were made as follows:

April 13, Sulphur-arsenate dust (pink spray)
April 16, Bordeaux Spray (pink spray)†
April 18, Dry lime sulphur spray (pink spray)
April 27, All materials (calyx spray)
May 24, All materials

The sulphur-arsenate dust was used at the rate of about one pound per tree and the spray at from two and one-half to three gallons per tree. The Bordeaux spray was applied under difficulties, which resulted in a very poor application.

*A more complete schedule of applications was intended, but the entry of this country into the World War disorganized the Plant Pathology Department quite seriously and prevented carrying out the spray program.

†The delay in the first applications of spray was due to the breaking of the pump.

TABLE 2.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected July 9, 1918.

TREATMENT	BLACK ROT LEAF SPOT: Distribution of Percentages of Leaves Showing Various Numbers of Spots per Leaf									SCAB: Distribution of Percentages of Leaves Showing Various Degrees of Scab					Percentage of Leaves Missing†	Number of Leaves Examined
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots	25-49 Spots	50-74 Spots	75 or more Spots	Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	None	Light	Medium	Heavy	Percentage of Leaves Showing Scab		
Untreated					29.6	31.1	39.3	**100.0**	**60.1**	**41.3**	12.5	16.5	29.7	**58.7**	10.4	448
Lime Sulphur Spray	**40.5**	13.3	11.6	19.5	15.1			**59.5**	**17.3**	**70.8**	7.5	13.7	8.1	**29.3**	*	482
Sulphur Dust	**49.7**	24.6	10.6	11.0	4.1			**50.3**	**9.7**	**62.1**	8.7	15.6	13.6	**37.9**	*	538
Bordeaux Spray	**40.0**	41.5	10.8	6.8	0.8			**59.9**	**5.8**	**78.0**	7.4	11.0	3.6	**22.0**	*	472

†The missing leaves were doubtless badly diseased, but percentages were figured on the basis of leaves examined.
*Less than one percent of leaves gone.

Typical twigs for leaf data were collected on July 8. In choosing materials for leaf data care was exercised to select terminal growths which fairly represented the general conditions and these were taken from different portions of the tree.

Table 2 shows the very heavy infection from leaf spot, and the average number of spots per infected leaf in the check plot is worthy of special note. The scab infection was also quite heavy. The greater number of leaves free from leaf spot in the dusted plot than in the Bordeaux plot was offset by more spots per leaf. The dust showed very good control of leaf spot and fair control of leaf scab, but a glance at Table 3 shows that scab control on fruit was very slight in the case of dust. The fact that both sprays were delayed would normally be a handicap in favor of the dust, but the Bordeaux was thoroughly effective, although a further delay, such as was required for the lime-sulphur, might have been more serious.

TABLE 3.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruit. Fruit harvested September 30 to October 2, 1918.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruits	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Untreated			6.2	93.8	100.0	100.0	1153
Dry Lime-Sulphur Spray	2.2	12.7	12.8	72.3	97.8	95.8	1441
Sulphur Dust	8.5	34.2	35.2	22.1	91.5	88.1	2016
Bordeaux Spray	76.4	17.4	4.4	1.8	23.6	19.3	1724

EXPERIMENTS IN 1919

The experiments in 1919 were conducted in the J. H. Stewart orchard at Raymond City on thirteen year old Rome trees. The equipment consisted of a large power Niaraga duster and a Bean power sprayer. Several new materials were tested and, in the case of Bordeaux spray, some data were secured as to the most important time of application. The materials used were 90-10 sulphur-arsenate dust; 3-5-50 Bordeaux mixture; dry lime-sulphur spray, 3½ pounds to 50 gallons; and three special dusts as follows:

TABLE 4.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected July 18, 1919.

TREATMENT	BLACK ROT LEAF SPOT						SCAB					Number of Leaves Examined
	Distribution of Percentages of Leaves Showing Various Numbers of Spots per Leaf				Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	Distribution of Percentages of Leaves Showing Various Degrees of Scab				Percentage of Leaves Showing Scab	
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots			None	Light	Medium	Heavy		
Sulphur Dust	39.2	45.5	9.7	1.6	60.8	2.8	30.2	66.6	2.9	0.3	69.8	311
Bordeaux Spray Applications 2 and 3	47.5	45.4	5.6	1.5	52.5	2.5	40.8	58.2	1.0	0.0	59.2	196
Bordeaux Spray Applications 1, 2, and 3	46.7	49.2	4.1	0.0	53.3	2.2	36.4	62.6	1.0	0.0	63.6	195
Bordeaux Spray Application 3	21.2	53.4	21.2	4.2	78.8	3.9	16.6	82.4	1.0	0.0	83.4	193
Untreated	21.9	32.3	21.9	21.9	78.1	6.4	24.6	62.9	6.6	5.5	75.4	183
Lime-Sulphur Spray	65.0	33.6	1.4	0.0	35.0	2.0	38.5	61.5	0.0	0.0	61.5	288
Dust No. 2	38.5	50.3	9.9	1.3	61.5	2.8	31.2	61.8	7.0	0.0	68.8	223
Dust No. 3	41.5	46.1	8.7	3.7	58.5	3.6	31.2	67.2	1.2	0.0	68.8	241
Dust No. 5	25.4	41.1	25.4	8.1	74.6	5.0	43.2	53.8	3.0	0.0	56.8	197

Dust No. 2

3-5-50 Bordeaux dried and ground	50%
Hydrated lime	47.5%
Acacia	2.5%

Dust No. 3

Dehydrated copper sulphate	20%
Hydrated lime	78%
Copper carbonate	2%

Dust No. 5

Dry lime sulphur	50%
Rye flour	50%

The acacia and the rye flour were used with a view to increasing the adhesiveness of the dusts. The sulphur-arsenate dust and the lime-sulphur rye-flour dust were applied at the rate of about one pound per tree, while the copper dusts were used at the rate of about one-half pound per tree.

Applications were made as follows:

April 18, Bordeaux spray (pink spray)
April 19, Lime sulphur spray and all dusts (pink spray)
May 3, Lime sulphur spray (calyx spray)
May 5, Bordeaux spray and all dusts (calyx spray)
May 28, Bordeaux spray and lime sulphur spray
May 29, All dusts

On the Bordeaux plots shown in Tables 4 and 5, application 1 was made April 18; application 2, May 5; and application 3, May 28.

It may be noted from Table 4 that the amount of leaf spot was much less than in 1918 while the amount of leaf scab was greater. Very few of the leaves showed either medium or heavy scab infection, but there were spots on a very high percentage of the leaves. The first two or three leaves on a terminal (the oldest leaves) were most often free of scab infection. The leaf spot was most severe on leaves 2 to 6 of terminal growth, (leaf 2 being the second large leaf to emerge from the bud).

Practically no leaves had fallen at the time of taking data (July 18). Leaf samples from the Bordeaux plot receiving applications 1 and 2 were accidentally omitted.

The lime-sulphur spray gave most effective control of leaf spot while none of the materials reduced the amount of leaf scab infection very markedly.

The data given in Table 5 were taken on all the fruit from one tree each in the case of Dust No. 2, Dust No. 3, and Dust No. 5, while all the fruit from three trees was used in the case of the check plot. The fruit in each of the other plots was all harvested separately and

TABLE 5.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruit. Fruit harvested September 24 and 25, 1919.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruit	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Sulphur Dust	17.1	37.7	24.5	20.7	82.9	100.0	657
Bordeaux Spray, Applications 1 and 2	61.5	15.1	16.5	6.9	38.5	100.0	509
Bordeaux Spray, Applications 2 and 3	59.5	20.8	17.0	2.7	40.5	97.3	447
Bordeaux Spray, Applications 1, 2, and 3	70.2	15.4	11.3	3.1	29.8	84.5	521
Bordeaux Spray, Application 3	1.7	10.7	19.2	68.4	98.3	100.0	479
Untreated	1.6	9.1	19.5	69.8	98.4	100.0	374
Lime-Sulphur Spray	45.9	23.6	18.9	11.6	54.1	100.0	567
Dust No. 2	4.1	25.1	30.8	40.0	95.9	100.0	195
Dust No. 3	12.9	33.3	24.6	29.2	87.1	100.0	171
Dust No. 5	1.2	15.8	31.6	51.4	98.8	100.0	171

piled up. Then a typical three bushel sample was taken for the purpose of securing individual fruit data. Some idea may be obtained as to the relative size of the fruits by noting the number required for three bushels in the sulphur dust, lime-sulphur spray, and the various Bordeaux spray plots (last column, Table 5).

The fruit infection from scab, and sooty blotch was fully as severe as in 1918. Sooty blotch was not satisfactorily controlled by any of the materials used. The Bordeaux spray was very effective against scab, and it would seem that the second (calyx) application was the most important under the conditions existing in that orchard during the 1919 season. The earlier applications are undoubtedly of great importance many seasons. The lime-sulphur spray was next in effectiveness and sulphur-arsenate dust next, although none of the dusts was at all satisfactory.

EXPERIMENTS IN 1920

During the season of 1920 the experiments were again conducted in the Stewart orchard at Raymond City, and also in the Bowers orchard at Bunker Hill.

New materials tested in connection with this work were:

Dust No. 6

Bug Death, (a commercial proprietary compound containing a high percentage of zinc oxide).

Dust No. 7

Superfine sulphur	75%
Dry lime sulphur	15%
Arsenate of lead	10%

Dust No. 8

Dehydrated copper sulphate	15%
Hydrated lime	60%
Venetian red (Ferric oxide)	15%
Arsenate of lead	10%

Dust No. 9

Commercial Bordeaux dust (11% copper)	45%
Hydrated lime	45%
Arsenate of lead	10%

The standard 90-10 sulphur-arsenate dust, 3-5-50 Bordeaux spray, and 1-40 lime-sulphur spray were also used.

At Raymond City

In the experiments at Raymond City the trees were of the Rome variety and fourteen years old. The equipment consisted of a large power Niagara duster and a Bean power sprayer.

Applications were made as follows:

April 23, Dry lime sulphur spray
April 24, Bordeaux spray
April 30, Dusts
May 6, Bordeaux and lime sulphur sprays
May 12, Dusts
May 15, Dusts
May 26, Bordeaux and lime sulphur sprays
June 1, Dusts
June 25, Bordeaux and lime sulphur sprays
June 30, Dusts

There was some delay in making the first application of dust, and the trees were nearly in bloom at that time.

Leaf spot and scab were considerably more severe in 1920 than in 1919, but Table 6 shows that very effective control was secured with dust as well as spray. The results would indicate that practically no scab infection had taken place on April 30. The dust No. 7 (sulphur-lime-sulphur) appeared to be more effective than any other material used, while Bordeaux spray was next in value.

The fruit infection on unsprayed trees as shown in Table 7 was nearly a hundred percent for both scab and sooty blotch. In the

TABLE 6.—The effectiveness of certain treatments in preventi ng leaf spot and scab on apple. Leaves collected July 12, 1920.

TREATMENT	BLACK ROT LEAF SPOT: Distribution of Percentages of Leaves Showing Various Number of Spots per Leaf					BLACK ROT LEAF SPOT		SCAB: Distribution of Percentages of Leaves Showing Various Degree of Scab				SCAB	
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots	25-49 Spots	Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	None	Light	Medium	Heavy	Percentage of Leaves With Scab	Number of Leaves Eamined
Untreated	**20.0**	18 4	12.0	19 2	30.4	**80 0**	**20.8**	**46 4**	19 2	8 0	26 4	**53 6**	125
Sulphur Dust	**53.6**	34 5	11.9	0 0	0 0	**46.4**	**3 5**	**89 9**	10 1	0 0	0 0	**10.1**	168
Bordeaux Spray	**67.1**	26 5	6 4	0 0	0 0	**32 9**	**2 8**	**92 3**	7 7	0.0	0 0	**7.7**	234
Dust No. 7	**73.6**	25.6	0 8	0 0	0 0	**26 4**	**1 7**	**96 1**	3 6	0 3	0 0	**3 9**	358
Dust No. 8	**35.2**	41 5	13 6	9 7	0 0	**64 8**	**5 0**	**83 7**	14 3	1 3	0 7	**16 3**	154
Dust No. 9	**39.6**	33.5	17 9	9.0	0 0	**60 4**	**5 0**	**85 1**	13 4	1 5	0 0	**14 9**	134

TABLE 7.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruits. Fruit harvested September 18 to 21, 1920.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruit	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Sulphur Dust	28.8	23.6	21.6	26.0	71.2	79.7	901
Untreated	4.8	18.3	37.4	39.5	95.2	99.5	1292
Bordeaux Spray	78.5	8.1	7.8	5.6	21.5	5.0	1045
Dust No. 7	48.2	19.7	14.4	17.7	51.8	64.2	1141
Dust No. 8	40.2	38.5	8.7	12.8	59.8	82.6	1298
Dust No. 9	9.4	39.9	24.9	26.1	90.6	61.9	593

control of these diseases on apples the Bordeaux spray stands out by itself. The dust No. 7 was slightly more effective than any of the other dusts, but could not be considered satisfactory.

At Bunker Hill

In the experiments at Bunker Hill the work was conducted in the Bowers orchard on trees of the Ben Davis variety, eighteen years old. The equipment consisted of a small Kansas City power duster and a Domestic power sprayer.

Applications were made as follows:

April 26, All materials (pink spray)
May 10, All materials (calyx spray)
May 17, Sulphur dust on special plot
May 22, All materials
May 27, Sulphur dust on special plot

The average amount of dust used per tree was:

Sulphur arsenate	1½ pounds
Dust No. 6	2 pounds
Dust No. 9	1 pound

The trees were dusted from both sides and nine trees in the sulphur-arsenate block received two extra applications, as may be seen in the schedule of applications. There was very little black rot leaf spot and no data on it were taken.

It may be seen from Table 8 that the sulphur dust gave fair control of leaf scab, but Bordeaux was most effective, and lime-sulphur

TABLE 8.—The effectiveness of certain treatments in preventing scab on apple. Leaves collected July 9, 1920.

TREATMENT	Distribution of Percentages of Leaves Showing Various Degrees of Scab				Percentage of Leaves With Scab	Percentage of Leaves Missing	Number of Leaves Examined
	None	Light	Medium	Heavy			
Sulphur Dust (5 applications)	**64.3**	23.8	10.9	0.5	**35.7**	5.2	193
Lime Sulphur Spray	**75.4**	24.6	0.0	0.0	**24.6**	5.3	228
Untreated	**14.4**	61.0	16.1	8.5	**85.6**	5.9	236
Bordeaux Spray	**98.2**	1.8	0.0	0.0	**1.8**	*	326
Dust No. 9	**37.6**	51.2	9.9	1.3	**62.4**	3.6	223
Dust No. 6	**57.6**	35.7	4.9	1.8	**42.4**	*	283

*Less than one percent of leaves gone.

spray next. There was a small percentage of leaf injury attributable to the Bordeaux.

The scab infection was rather uniformly distributed on all leaves, although leaves 8 to 10 and 14 to 16 on terminal growths showed the greatest amount of injury.

The greater efficiency of the sprays is brought out more markedly in the fruit data given in Table 9. The Bordeaux spray was very satisfactory and lime-sulphur quite good, while the amount of scab was reduced very little by any of the dusts.

TABLE 9.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruits. Fruit harvested October 19 to 21, 1920.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruits	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Sulphur Dust (3 Applications)	24.1	33.8	23.6	18.5	75.9	5.9	373
Sulphur Dust (5 Applications)	21.2	34.6	26.0	18.3	78.8	33.3	803
Lime-Sulphur Spray	54.0	28.3	12.6	5.1	46.0	7.6	1392
Untreated	8.9	20.0	31.7	39.4	91.1	10.2	1326
Bordeaux Spray	68.7	17.8	9.6	3.9	31.3	0.0	1250
Dust No. 9	19.6	35.3	29.5	15.7	80.4	12.8	1364
Dust No. 6	15.7	35.4	30.4	18.5	84.3	2.9	421

EXPERIMENTS IN 1921

The experimental work in 1921 was carried on at Raymond City and at Inwood. Special dusts used this season were:

Dust No. 7

Superfine sulphur	75%
Dry lime sulphur	15%
Arsenate of lead	10%

Dust No. 10

Superfine sulphur	70%
Dehydrated copper sulphate	5%
Hydrated lime	15%
Arsenate of lead	10%

The standard 90-10 sulphur-arsenate dust was also used in both orchards.

At Raymond City

In the experiments at Raymond City the trees were of the Rome variety, fifteen years old. The equipment consisted of a large power

TABLE 10.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected June 25, 1921.

TREATMENT	BLACK ROT LEAF SPOT: Distribution of Percentages of Leaves Showing Various Number of Spots per Leaf							BLACK ROT LEAF SPOT		SCAB: Distribution of Percentages of Leaves Showing Various Degrees of Scab				SCAB	Percentage of Leaves Missing	Number of Leaves Examined
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots	25-49 Spots	50-74 Spots	75 or more Spots	Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	None	Light	Medium	Heavy	Percentage of Leaves With Scab		
Untreated	11.6	14.6	11.7	15.2	16.1	11.9	18.8	78.4	41.1	59.4	14.0	11.3	15.5	40.6	11.1	335
Sulphur Arsenate Dust	71.6	24.6	3.5	0.3				28.4	2.5	79.5	9.4	9.2	1.9	20.5	*	371
Dust No. 10	70.0	25.9	3.3	0.8				30.0	2.5	87.2	8.2	3.6	1.0	12.8	*	390
Dust No. 7	77.3	20.6	2.1	0.0				22.7	2.2	90.7	3.6	4.1	1.6	9.3	*	438

*Less than one percent of leaves gone.

Niagara duster. Late spring frosts destroyed practically all prospect of fruit and it was found impracticable to use a spray outfit. The trees were in blossom unusually early and the first application was made as the petals were falling.

Applications were made as follows:

April 15, All dusts
April 21, All dusts
May 7, All dusts

The trees were thoroughly dusted, from both sides, and received from one to one and one-half pounds per tree, each application.

Table 10 shows that there was very serious injury from leaf spot on unsprayed trees, and many leaves showed more than one hundred spots per leaf. There was not much early infection, and the first three to five leaves on terminal growths (oldest leaves) were comparatively free from leaf spot. Many of the badly infected leaves (11.1%) had already fallen on June 25 when the samples were collected. Most of the scab infection on leaves occurred quite late and the four or five youngest leaves were most injured by it.

All the dust materials were quite effective in controlling leaf infections of both scab and leaf spot.

The fruit data in Table 11 is not very satisfactory because there were very few apples and these were scattered irregularly over the trees. In the case of the check plot seventy-six apples were harvested from seven trees. This included all the apples on the trees and some drops. None of the dusts gave satisfactory control of scab on fruit.

TABLE 11.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruit. Fruit harvested September 16 to 18, 1921.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruit	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Untreated	**5.2**	18.5	50.0	26.3	**94.8**	100.0	76
Sulphur-Arsenate Dust	**23.7**	16.2	42.6	17.5	**76.3**	100.0	704
Dust No. 10	**19.9**	33.4	31.1	15.6	**80.1**	100.0	612
Dust No. 7	**23.1**	43.5	20.5	12.9	**76.9**	100.0	225

TABLE 12.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected July 6, 1921.

TREATMENT	BLACK ROT LEAF SPOT						SCAB					Percentage of Leaves Missing	Number of Leaves Examined
	Distribution of Percentages of Leaves Showing Various Numbers of Spots per Leaf				Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	Distribution of Percentages of Leaves Showing Various Degrees of Scab				Percentage of Leaves Showing Scab		
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots			None	Light	Medium	Heavy			
Untreated	37.0	53.1	9.4	0.5	63.0	2.8	44.2	11.8	18.7	25.2	65.8	4.1	416
Sulphur-Arsenate Dust	57.0	41.7	1.3	0.0	43.0	1.7	61.0	18.3	14.1	6.6	39.0	13.1	333
Dust No. 10	59.8	36.8	2.7	0.7	40.2	2.3	68.7	15.1	12.1	4.1	31.3	10.4	438
Dust No. 7	54.8	41.4	2.9	0.9	45.2	2.4	68.0	12.4	16.0	3.6	32.0	3.9	411

At Inwood

In the experiments at Inwood the work was conducted in the Silver Hill Orchard. The trees selected were of the Ben Davis variety, and about twenty years old. The equipment consisted of a small Niagara power duster.

The dates of application were:

April 12, All dusts
April 25, All dusts
May 6, All dusts

The average amount of material used per tree for each application was about two and one-half pounds of the sulphur-arsenate dust and Dust No. 7, and about two pounds of Dust No. 10. The trees were dusted from both sides.

Leaf spot infection was most severe on leaves 4 to 7, while the three oldest leaves and the younger ones were relatively free from it. Practically all the leaf scab infection took place even later and was most evident on leaves 5 to 10. It is, therefore, clear that these leaves became diseased after some dust applications had been made. Table 12 shows that both leaf spot and scab infections were reduced somewhat by each of the treatments, but none of the materials gave satisfactory control. At least a portion of the missing leaves could be attributed to frost injury.

The fruit was irregular and scattered on many trees as a result of late spring frost, and this renders the data less satisfactory. It may be seen in Table 13 that the sulphur-arsenate and Dust No. 10 plots showed most scab control, but the results do not speak well for any of the treatments.

TABLE 13.—The effectiveness of certain treatments in preventing scab on apple fruit. Fruit harvested September 21 to 24, 1921.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruits	Number of Fruits Examined
	None	Light	Medium	Heavy		
Untreated	**45.3**	45.3	6.4	3.0	**54.7**	530
Sulphur-Arsenate Dust	**71.0**	21.9	4.0	3.1	**29.0**	1720
Dust No. 10	**70.0**	24.1	4.6	2.3	**30.0**	1406
Dust No. 7	**52.4**	34.6	9.6	3.4	**47.6**	1638

TABLE 14.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected July 2, 1922.

TREATMENT	BLACK ROT LEAF SPOT: Distribution of Percentages of Leaves Showing Various Numbers of Spots per Leaf								SCAB: Distribution of Percentages of Leaves Showing Various Degrees of Scab					
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots	25-49 Spots	50-75 Spots	Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	None	Light	Medium	Heavy	Percentage of Leaves Showing Scab	Number of Leaves Examined
Untreated	28.7	19.2	17.2	23.6	10.2	1.1	71.3	17.5	77.4	16.8	3.4	2.4	22.6	623
Sulphur-Arsenate Dust	76.7	23.3	0.0				23.3	2.1	91.1	7.7	1.2	0.0	8.9	795
Bordeaux Spray	75.0	24.5	0.5				25.0	1.9	93.0	6.7	0.3	0.0	7.0	859
Dry Lime Sulphur Spray	80.3	18.8	0.9				19.7	1.8	92.5	6.2	0.6	0.7	7.5	724
Lime Sulphur Spray	68.3	30.6	1.1				31.7	1.6	92.3	6.4	0.6	0.7	7.7	987
Dust No. 11	83.4	15.8	0.8				16.6	1.7	94.1	4.9	1.0	0.0	5.9	783
Dust No. 12	59.1	33.7	6.3	0.9			40.9	3.1	88.6	7.8	2.1	1.5	11.4	769

EXPERIMENTS IN 1922

The work in the eastern part of the state was transferred from Inwood to Keyser, where a suitable orchard and better equipment were available, while the work in the western part of the state was continued at Raymond City.

Late frosts again interfered with the work by destroying practically all fruit in both experimental orchards. Special dusts used were:

Dust No. 11

Superfine sulphur	80%
Dry lime sulphur	10%
Arsenate of lead	10%

Dust No. 12

Dosch copper-lime dust B-8 (containing 12% monohydrated copper sulphur and 12.5% lead arsenate)

At Raymond City

The trees in the experimental work at Raymond City were of the Rome variety, sixteen years old. The equipment consisted of a large Niagara power duster and a Bean super giant sprayer. The materials used were 90-10 sulphur arsenate dust, special dust No. 11, special dust No. 12, 3-5-50 Bordeaux spray, 1-40 standard lime-sulphur spray, and the dry lime-sulphur spray. About ¾ pound to one pound of dust per tree per application was used in the case of sulphur-arsenate dust and Dust No. 11, while the Dust No. 12 averaged ½ to ¾ pound per tree.

Applications were made as follows:

April 10, All applications (pink spray)
April 22, All applications (calyx spray)
May 6, All applications
May 23, All applications
June 12, All applications

Scab was not very prevalent and very few leaves showed more than a small area of infection, but leaf spot was quite severe as may be noted in the data in Table 14. There were a few scab spots on leaves 2 to 4, but most of the infection was on leaves 9 to 12, near the tip of terminal growths. Leaves 1 to 3 were quite generally free from leaf spot, while the heaviest infection occurred on leaves 6 to 8. Some of the scab infection took place earlier, but most of it occurred later than the main leaf spot infection.

Each of the treatments was quite effective in reducing the amount of leaf injury from both scab and leaf spot.

At Keyser

In the experiments at Keyser the work was conducted in the Knobley Mountain Orchard upon Rome apple trees about fourteen years old.

TABLE 15.—The effectiveness of certain treatments in preventing leaf spot and scab on apple. Leaves collected July 12, 1923.

TREATMENT	BLACK ROT LEAF SPOT: Distribution of Percentages of Leaves Showing Various Numbers of Spots per Leaf						BLACK ROT LEAF SPOT: Percentage of Infected Leaves	BLACK ROT LEAF SPOT: Average Number of Spots per Infected Leaf	SCAB: Distribution of Percentages of Leaves Showing Various Degrees of Scab				SCAB: Percentage of Leaves Showing Scab	Number of Leaves Examined
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots	25-49 Spots	50-74 Spots			None	Light	Medium	Heavy		
Untreated	11.2	21.0	14.7	31.7	19.2	2.2	88.8	15.9	87.6	5.5	4.6	2.3	12.4	652
Sulphur-Arsenate Dust	74.0	25.6	0.4	0.0			26.0	1.6	98.7	1.3			1.3	795
Bordeaux Spray	75.8	23.8	1.4	0.0			24.2	1.9	100.0	0.0			0.0	433
Lime-Sulphur Spray	60.2	35.8	3.3	0.7			39.8	2.3	100.0	0.0			0.0	575
Dry Lime-Sulphur Spray	54.8	39.4	5.1	0.6			45.2	2.5	100.0	0.0			0.0	631
Dust No. 12	60.0	28.8	5.3	5.9			40.0	4.4	100.0	0.0			0.0	372
Dust No. 7	77.6	21.6	0.8	0.0			22.4	1.7	99.5	0.5			0.5	625

Late frosts destroyed practically all fruit and injured the foliage very seriously, so that the experiment was not carried through to completion, and no data were secured.

EXPERIMENTS IN 1923

The work in the eastern part of the state was again transferred to Inwood, and arrangements were made for securing some data from a large orchard at Rada. The work at Raymond City was continued.

At Raymond City

The trees in the experimental work at Raymond City were of the Rome variety, seventeen years old. The equipment consisted of a large Niagara power duster and a Bean super giant sprayer. The materials used were 90-10 sulphur-arsenate dust, Dosch copper-lime dust B-8 (special dust No. 12), sulphur-lime-sulphur dust (special dust No. 7), 3-5-50 Bordeaux spray, 1-40 lime-sulphur spray, and dry lime-sulphur spray.

Applications were made as follows:

April	20,	All materials (pink spray)
May	4,	All materials (calyx spray)
May	18,	All materials
June	7,	All materials
July	12,	All materials

About one and one-fourth pounds of material per tree, per application, were used, of sulphur dust and sulphur-lime-sulphur dust, while about three-fourths pound was used in the case of Dust No. 12.

Leaf spot infection was quite general and severe but the scab injury was negligible as shown in Table 15. Leaves 1 and 2 were generally free of leaf spot, while the heaviest infection occurred on leaves 5 to 9 of terminal growths. Scab spots were found almost exclusively on leaves 7 to 10.

Each of the materials was quite effective in reducing leaf spot injury. The Dust No. 7 (sulphur-lime-sulphur) appeared to be best, and the sulphur arsenate dust ranked about equal to the Bordeaux spray. Each treatment was also very satisfactory in controlling leaf scab, although the amount of infection on check trees was slight.

The amount of scab infection on fruit as shown in Table 16 was too slight to be of any significance, but there was one hundred percent sooty blotch infection on unsprayed trees. The sooty blotch was almost completely controlled by Bordeaux and lime-sulphur sprays, while the Dust No. 7 (sulphur-lime-sulphur) and sulphur-arsenate dusts were also very effective in controlling it.

TABLE 16.—The effectiveness of certain treatments in preventing scab and sooty blotch on apple fruit. Fruit harvested September 20 to 22, 1923.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruits	Percentage of Fruits Affected by Sooty Blotch	Number of Fruits Examined
	None	Light	Medium	Heavy			
Untreated	96.0	2.9	0.4	0.7	4.0	100.0	1040
Dust No. 12	88.6	8.2	1.8	1.4	11.4	21.7	1326
Sulphur Dust	93.3	3.9	1.2	1.6	6.7	9.2	1021
Bordeaux Spray	95.2	2.5	0.6	1.7	4.8	3.0	1061
Lime-Sulphur Spray	99.2	0.2	0.2	0.4	0.8	0.8	500
Dry Lime-Sulphur Spray	99.2	0.4	0.2	0.2	0.8	20.0	500
Dust No. 7	96.2	2.7	0.5	0.6	3.8	8.1	1000

At Inwood

In the experiments at Inwood the work was conducted in the Silver Hill Orchard, and the trees were Ben Davis variety, twenty-two years old. The equipment consisted of a large Dosch power duster and a Stewart Supersprayer.

The materials used were 90-10 sulphur-arsenate dust, Dust No. 7 and Dust No. 12.

Applications were made as follows:

April 26, All materials (pink spray)
May 7, All materials (calyx spray)
May 19, All materials
May 31, All materials

The amounts of dust used per tree per application were approximately three pounds each of sulphur-arsenate and of sulphur-lime-sulphur, and two pounds of the Dosch copper-lime.

There was practically no scab infection on leaves, and it may be seen from Table 17 that the amount of leaf spot was relatively small. Leaf data were not secured from the sprayed plot. None of the treatments was effective in controlling leaf spot.

Table 18 shows that there was a moderate amount of scab infection on the fruit but that it was well controlled by both of the sulphur dusts and the spray.

TABLE 17.—The effectiveness of certain treatments in preventing black rot leaf spot on apple. Leaves collected July 10, 1923.

TREATMENT	Distribution of Percentages of Fruits Showing Various Number of Spots per Leaf				Percentage of Infected Leaves	Average Number of Spots per Infected Leaf	Number of Leaves Examined
	No Spots	1-4 Spots	5-9 Spots	10-24 Spots			
Untreated	63.3	35.3	1.2	0.2	36.7	1.8	470
Sulphur-Arsenate Dust	62.0	37.4	0.6	0.0	38.0	1.6	443
Dust No. 7	56.4	41.8	1.8	0.0	43.6	1.8	540
Dust No. 12	50.5	43.8	4.3	1.4	49.5	2.5	420

TABLE 18.—The effectiveness of certain treatments in preventing scab on apple fruit. Fruit harvested October 14 to 15, 1923.

TREATMENT	Distribution of Percentages of Fruits Showing Various Degrees of Scab				Percentage of Scabby Fruit	Number of Fruits Examined
	None	Light	Medium	Heavy		
Untreated	64.8	25.2	6.8	3.2	35.2	2330
Sulphur Dust	96.8	2.8	0.4	0.0	3.2	2480
Dust No. 12	90.0	6.3	3.0	0.7	10.0	2002
Dust No. 7	98.5	0.0	0.0	1.5	1.5	2740
Lime-Sulphur Spray	98.8	0.9	0.3	0.0	1.2	2330

At Rada

A block of Rome apple trees about twelve years old was selected for the experimental work at Rada. A large Niagara power duster and a power sprayer were used. Bordeaux dust was used except for the application ten days after petal fall. The 90-10 sulphur-arsenate dust was used for the application ten days after petal fall, and Niagara copper-lime dust for apples was used for all others.

Applications were made as follows:

May 1, Lime sulphur spray (pink spray)
May 2, Copper lime dust (pink spray)
May 14, Copper lime dust and lime sulphur spray (calyx spray)
May 24, Lime sulphur spray
May 25, Sulphur lime dust
June 1, Copper lime dust
June 14, Copper lime dust
June 28, Copper lime dust

Six applications were made on the dusted plot. Complete data were not secured, but the owner reported no success whatever in controlling scab with the dust, while spray was very satisfactory. The fruit from the dusted plot was kept separate when it was sent to the packing house and the inspector there reported very heavy scab infection on fruit from dusted plots but practically none on fruit from sprayed plots. Some boxes of typical fruit from the two plots were sent to the laboratory at Morgantown and furnished evidence that the statements of the owner and the inspector were correct.

EXPERIMENTS IN 1924

The work at Raymond City was discontinued in 1924, but the experiments were carried on at Inwood. The copper-lime dusts were discontinued because they had been found to cause considerable injury to fruit and foliage and they were not so effective as the sulphur dusts for the control of the diseases in question. The sulphur-lime-sulphur dust was also omitted as it did not appear to be enough more efficient than sulphur to warrant the extra cost of the material.

The 90-10 sulphur-arsenate was the only material used. Forty-five of the trees were dusted on both sides on the same date; while seventy trees were dusted twice as many times, but using the dust alternately on one side of the trees and then a few days later on the other side. Late frosts destroyed a large portion of the fruit in the section of the orchard where the experiments were under way and the remaining fruit was so badly russeted by frost that no effort was made to secure data from the plots.

DISCUSSION AND SUMMARY

The question, as to the practicability of apple orchard dusting in West Virginia, has seemed to be a matter of great economic importance to everyone interested in orcharding, and every reasonable effort has been made to secure satisfactory control of the prevailing orchard diseases by the use of dust mixtures.

It is entirely possible that the development of new materials or equipment may make dusting a more satisfactory treatment against

our most prevalent and destructive plant diseases. The authors are, however, inclined to the opinion that the problem of disease control in commercial apple orchards of West Virginia is likely to be solved in other ways, so far as the immediate future is concerned.

In our mountain section the varying and almost incessant winds are a serious handicap to the successful application of dust mixtures and it is very difficult for commercial orchardists to find laborers who are willing to be on the job at the hours best suited for making dust applications.

The leaf infection data secured during several seasons gave evidence indicating the approximate time of leaf spot and scab infections, as well as showing the relative amount of disease on foliage. Leaf data from check trees covering four years in the Stewart orchard and three years in other orchards did not show in any case a heavy general infection of the first three (oldest) large leaves on terminal growths. Isolated cases of fairly heavy infections of the first three leaves did occur and the twigs bearing such leaves were doubtless located close beneath some branches heavily infected with the black rot fungus.

Cone shaped areas of infection may frequently be found just beneath a dead twig or branch, and such infections often take place at about the time the trees come into bloom. In the orchards observed there was, however, a later, general infection of foliage by the leaf spot organism. It was this general infection which caused most of the injury. The fact that the first leaves were so often immune at the time of infection indicates that destructive black rot leaf spot infections do not normally occur until after petal fall, under West Virginia conditions.

The successful control of leaf spot was undoubtedly due in part to the fact that the general infection usually occurred soon after the ten day or two-weeks application, and in part of the non-progressive nature of the disease. The leaf spot infection does not normally spread from leaf to leaf, as is the case with scab.

Scab infection was also very light on the first three leaves, although there was rather general but light infection on these leaves in 1919. Heavy scab infection was practically never found until the sixth or seventh leaf was reached and most infection was on leaves eight to ten, well out toward the tip.

This infection data would indicate that under West Virginia conditions, both scab and leaf spot should be readily controlled by thorough applications of fungicides beginning in the cluster bud or pink stage.

CONCLUSION

Experiments extending over a period of eight years, including different locations and orchards, indicated that dust mixtures, at their present stage of development, were not effective or satisfactory, for the control of several outbreaks of apple scab, under West Virginia conditions.

Dust mixtures were more satisfactory for the control of black rot leaf spot than for scab, and gave better control of scab on foliage than on fruit.

Upon varieties which are resistant to scab, or during seasons when the amount of scab infection is slight, the use of dust mixtures would undoubtedly be satisfactory in West Virginia commercial orchards.

Bulletin 210

November, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. GIDDINGS, Acting Director
Morgantown

Sunflower Silage vs. Corn Silage for Milk Production

By

H. O. HENDERSON and WARREN GIFFORD

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr., ... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY (Includes Genetics)

R. J. Garber, Ph. D.
Agronomist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. S.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Paul Daughenbaugh
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Assistant Plant Pathologist

L. H. Leonian, Ph. D.
Assistant Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*Sunflower Silage vs. Corn Silage for Milk Production**

During the past few years, the use of sunflower silage as a substitute for corn silage has aroused considerable interest. The interest has been particularly keen in those sections of the country where corn does not grow satisfactorily on account of climatic or other unfavorable conditions, or in sections of limited tillable acreage where it is difficult to grow sufficient silage and other roughage for dairy cows. A preliminary report was published by this Station in 1920, in which the results of one trial comparing the feeding value of corn silage and sunflower silage were given.† These results were such that it was thought that further study should be made in order to obtain more definite information as to the feeding value of sunflower silage as compared to corn silage. Accordingly, two more trials have been completed. The results of these, together with the results of the first trial are published in this bulletin. A report on a study of the culture of sunflowers is given in Bulletin 204 of this Station.

RESULTS AT OTHER STATIONS

Since the previous report was published in 1920, many of the experiment stations have reported experimental results on the use of sunflower silage. Only a brief summary of them is possible in this bulletin. A study of these reports shows a wide difference in the results obtained. Several of the stations report that sunflower silage was equal or superior to corn silage for the production of milk, *(3)*, *(4)*, *(5)*, *(7)*. Others report that it was inferior to corn silage *(1)*, *(2)*, *(6)*, *(8)*. Among these Bechdel of the Pennsylvania Station *(1)* found that the cows fed sunflower silage produced only about 86.4 percent as much as those fed an equal amount of corn silage. Schafer and Westley of the Washington Station *(8)* found that sunflower silage was 92 percent as valuable as corn silage for milk and butterfat production. Nevens of the Illinois Station *(6)* obtained from 15 to 25 percent more milk when the cows were fed corn silage than when they were fed sunflower silage. Hicks of the Agassiz, B. C. Experiment Farm *(2)* obtained an average milk production with corn silage of 33.6 pounds and with sunflower silage 31.52 pounds.

---

*Submitted for publication April, 1926. At the time this experiment was conducted Mr. Gifford, the junior author, was a member of this Station staff. He resigned July 1, 1926, to join the faculty of the College of Agriculture, University of Missouri.

†West Virginia Experiment Station Circular 32.

In regards to palatability the reports also differ. Some of the stations *(4)*, *(5)* found that sunflower silage was palatable to livestock. Others, however, *(1)*, *(3)*, *(6)*, *(8)* found that sunflower silage showed a distinct lack of palatability as compared to corn silage. Nevens *(6)* found that the time of cutting had a great influence upon palatability, the earlier cuttings being more palatable than later ones. This was the most decisive factor in determining the value of the sunflower at the different stages of cutting.

THE PLAN OF THE EXPERIMENT

Two well balanced groups of cows were used in each of the three trials and are designated as Groups 1 and 2 in Trial I, Groups 3 and 4 in Trial II, and Groups 5 and 6 in Trial III. Care was taken to divide the groups in each trial so that they were as nearly uniform as possible in regard to breed, weight, stage of lactation, and amount of milk and butterfat which they were producing. The plan, however, was not to compare the two groups, but rather to compare the two feeding periods of the same group, using one group as a check against the other.

The different groups were fed for the period of the tests on a ration consisting of grain, hay, and silage. The ration was fed so that the cows were receiving an approximate nutritive balance of protein and energy as required by the Armsby Feeding Standard.

The grain ration in Trials I and III consisted of 200 pounds of cottonseed meal, 200 pounds of linseed meal, 300 pounds of wheat bran, and 100 pounds of ground barley, while that of Trial II consisted of 300 pounds of corn meal, 200 pounds of wheat bran, 200 pounds of gluten meal, 100 pounds of cottonseed meal, and 100 pounds of linseed meal.

The amount of grain fed depended upon the amount of milk produced. One pound of grain was fed to each three to four pounds of milk produced, the exact amount depending upon the percentage of fat in the milk. The amount of silage fed differed in the three trials. In Trial II, 30 pounds, Trial I, 35 pounds, and Trial III, 45 pounds were fed per day. It was thought best to feed as much as the cows would eat, so that the effects of the silages would be more pronounced.

The cows were placed on a week's preliminary feed in order to accustom them to the change of ration, after which the experiment was begun and continued for three weeks. The feeding was then changed so that the group which during the first three weeks was

getting corn silage was fed sunflower silage, and the group which was fed sunflower silage the first three weeks was then fed corn silage.

The weights of the cows in the different groups were taken on three consecutive days both at the beginning of the trial and at the end of each period. The average of these weights was taken as the weight for that particular time.

The milk from each cow was carefully weighed after each milking. A weekly composite sample was taken from each cow and tested for butterfat.

THE COWS AT THE BEGINNING OF THE TRIALS

Tables 1, 2, and 3 give the breed, weight, time of lactation, and average amount of milk produced by each cow for the seven days previous to the beginning of the trials.

TABLE 1.—Breed, Lactation, Production, and Weight of Cows in First Feeding Trial.

	Herd Number of Cow	Breed	Time in Lactation	Daily Milk Production in Pounds	Weight of Cows in Pounds
GROUP 1	22	Purebred Holstein	197 Days	25 8	930
	9	Grade Holstein	160 Days	21 6	1400
	21	Purebred Holstein	94 Days	28 6	1020
	5	Purebred Jersey	44 Days	34 6	760
	17	Grade Holstein	26 Days	41 6	1210
		Average	104 Days	30.4	1064
GROUP 2	7	Purebred Ayrshire	259 Days	16 3	1120
	6	Purebred Holstein	189 Days	32 1	1290
	16	Purebred Holstein	167 Days	43 7	1230
	23	Purebred Holstein	81 Days	32 5	970
	18	Purebred Ayrshire	44 Days	38 3	900
		Average	148 Days	32 6	1102

THE FIRST FEEDING TRIAL

In Trial I each cow in Group 1 was fed 35 pounds of sunflower silage and each cow in Group 2 was fed 35 pounds of corn silage for the first four weeks of the trial. The feeding of the groups was then changed so that during the second four week period Group 1 received corn silage and Group 2 received sunflower silage. Each cow received 10 pounds of mixed clover and timothy hay per day and one pound of grain for each 3.5 pounds of milk produced.

TABLE 2.—**Breed, Lactation, Production, and Weight of Cows in Second Feeding Trial.**

	Herd Number of Cow	Breed	Time in Lactation	Daily Milk Production in Pounds	Weight of Cows in Pounds
GROUP 3	48	Purebred Holstein	98 Days	21.2	1100
	4	Purebred Holstein	87 Days	39.7	1500
	50	Purebred Guernsey	65 Days	30.7	925
	43	Purebred Ayrshire	20 Days	41.3	1025
		Average	68 Days	33 2	1138
GROUP 4	47	Purebred Holstein	93 Days	29.0	1200
	16	Purebred Holstein	75 Days	41.2	1500
	52	Purebred Jersey	66 Days	20.9	670
	36	Purebred Holstein	13 Days	25 7	1200
		Average	62 Days	29 2	1143

TABLE 3.—**Breed, Lactation, Production, and Weight of Cows in Third Feeding Trial.**

	Herd Number of Cow	Breed	Time in Lactation	Daily Milk Production in Pounds	Weight of Cows in Pounds
GROUP 5	107	Purebred Guernsey	121 Days	17.9	1005
	132	Purebred Holstein	117 Days	16 3	1090
	106	Purebred Jersey	75 Days	14 5	795
	139	Purebred Ayrshire	67 Days	37.5	1145
	138	Purebred Ayrshire	57 Days	38 4	1060
		Average	87 Days	24 9	1019
GROUP 6	22	Purebred Holstein	291 Days	23.3	1120
	89	Purebred Jersey	205 Days	11.7	850
	100	Purebred Jersey	79 Days	16.3	1035
	137	Purebred Ayrshire	65 Days	41.1	1080
	136	Purebred Ayrshire	19 Days	34 7	972
		Average	132 Days	25.4	1012

Tables 4, 5, 6, and 7 give the production of the different cows by periods, a summary of the production by groups, the weight of each cow at the beginning and end of experiment, and a summary of the weights by groups. The production during the preliminary week is not included in these tables.

Tables 4 and 6 show that the five cows in Group 1, while being fed sunflower silage during a 21 day period, produced 3042.7 pounds of milk containing 121.27 pounds of butterfat, and lost a total of 140 pounds in weight. The same five cows, when fed corn silage

during a second 21 day period, produced 2865.6 pounds of milk containing 112.33 pounds of butterfat, and lost a total of 23 pounds in weight.

The five cows in Group 2, while being fed the sunflower silage, during a 21 day period, produced 2821.1 pounds of milk containing 98.64 pounds of butterfat, and lost a total of 47 pounds in weight. The same five cows when fed corn silage for a 21 day period, produced 3260.9 pounds of milk which contained 107.52 pounds of butterfat, and lost a total of 77 pounds in weight.

Bringing together the results of the two groups, Tables 5 and 7 show that the ten cows, while being fed sunflower silage during a 21 day period, produced 5863.8 pounds of milk and 219.91 pounds of butterfat, had an average butterfat test of 3.75 percent and lost a total of 187 pounds in weight. The same ten cows when fed corn

TABLE 4.—Production of Cows in First Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Pounds of Milk	Percent of Butterfat	Total Pounds Butterfat	Pounds of Milk	Percent of Butterfat	Total Pounds Butterfat
GROUP 1	22	503.4	3.97	20.00	543.2	3.53	19.20
	9	439.5	3.53	15.53	397.1	3.23	12.83
	21	538.6	3.68	19.81	525.8	3.40	17.87
	5	684.9	5.07	34.71	612.7	5.78	35.39
	17	876.3	3.56	31.22	786.8	3.44	27.04
	Total	3042.7	3.99	121.27	2865.6	3.92	112.33
	Herd Number of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 2	7	298.8	3.86	11.52	283.9	4.30	11.20
	6	692.4	3.17	21.92	625.4	3.31	20.68
	16	870.5	3.04	26.43	759.9	3.13	23.81
	23	692.7	2.97	20.55	554.6	3.40	18.86
	18	706.5	3.84	27.10	597.3	3.87	23.09
	Total	3260.9	3.30	107.52	2821.1	3.50	98.64

TABLE 5.—Summary of Production of Cows in First Trial.

Feeding Periods and Differences	Pounds of Milk Produced	Percent of Butterfat	Total Pounds of Butterfat
Sunflower Silage Period	5,863.8	3.75	219.91
Corn Silage Period	6,126.5	3.59	219.85
Difference in Favor of Corn Silage	262.7		
Difference in Favor of Sunflower Silage		0.16	0.06

TABLE 6.—Weight of Cows in First Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Weight at Beginning (Pounds)	Weight at End of First Period (Pounds)	Gain or Loss (—) in Weight During First Period (Pounds)	Weight at Begining of Second Period (Pounds)	Weight at End of Second Period (Pounds)	Gain or Loss (—) in Weight During Second Period (Pounds)
GROUP 1	22	930	900	—30	925	932	7
	9	1400	1390	—10	1385	1395	10
	21	1020	990	—30	990	975	—15
	5	760	730	—30	750	737	—13
	17	1210	1170	—40	1175	1163	—12
	Total	5320	5180	—140	5225	5202	—23
	Herd No. of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 2	7	1120	1110	—10	1100	1112	12
	6	1290	1240	—50	1255	1225	—30
	16	1230	1210	—20	1215	1192	—23
	23	970	990	20	995	1007	12
	18	900	883	—17	880	862	—18
	Total	5510	5433	—77	5445	5398	—47

TABLE 7.—Summary of Weights of Cows in First Trial.

Feeding Periods and Difference	Weight of Cows at Beginning (Pounds)	Weight of Cows at End (Pounds)	Gain or Loss (—) in Weight (Pounds)
Sunflower Silage Period	10,765	10,578	—187
Corn Silage Period	10,735	10,635	—100
Difference in Favor of Corn Silage			87

silage for a period of similar length produced 6126.5 pounds of milk and 219.85 pounds of butterfat, had a butterfat test of 3.59 percent, and lost 100 pounds in weight.

THE SECOND FEEDING TRIAL

In Trial II, each cow in Group 3 was fed 30 pounds each of sunflower silage and those in Group 4 were fed 30 pounds of corn silage daily for the first four weeks.

The feeding of the groups was then changed so that Group 3 was fed corn silage and Group 4 was fed sunflower silage during the second four weeks of the trial. Each cow in both groups was fed eight pounds of alfalfa hay daily, and one pound of the grain ration to each 3.5 pounds of milk produced.

Tables 8, 9, 10, and 11 give the production of the different cows by periods, a summary of the production by groups, the weights at the beginning and end of the experiment, and a summary of the weights by groups.

Tables 8 and 10 show that the four cows in Group 3, while being fed sunflower silage during a 21 day period, produced 2664.5 pounds of milk and 99.6 pounds of butterfat and lost a total of 146 pounds in weight. The same four cows, when fed corn silage for a 21 day period, produced 2405.6 pounds of milk and 85.61 pounds of butterfat, and gained a total of 100 pounds in weight. The four cows in Group 4, when fed sunflower silage during a 21 day period, produced 2114.0 pounds of milk, 70.37 pounds of butterfat, and gained a total of 40 pounds in weight. The same four cows, when fed corn silage during a period of similar length, produced 2280.9 pounds of milk, 78.76 pounds of butterfat, and lost a total of 43 pounds in weight.

TABLE 8.—Production of Cows in Second Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Pounds of Milk	Percent of Butterfat	Total Pounds Butterfat	Pounds of Milk	Percent of Butterfat	Total Pounds of Butterfat
GROUP 3	48	409.2	3.60	14.73	443.6	3.40	15.08
	4	795.8	3.28	26.13	746.8	3.08	23.03
	50	609.5	4.20	25.60	509.3	4.45	22.64
	43	850.0	3.90	33.14	705.9	3.52	24.86
	Total	2664.5	3.74	99.60	2405.6	3.56	85.61
	Herd No. of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 4	47	558.3	3.83	21.36	525.1	3.23	16.97
	16	708.7	3.00	21.26	693.5	2.95	20.48
	52	402.1	4.07	16.36	337.7	4.41	14.88
	36	611.8	3.23	19.78	557.7	3.23	18.04
	Total	2280.9	3.45	78.76	2114.0	3.33	70.37

TABLE 9.—Summary of Production of Cows in Second Trial.

Feeding Periods and Difference	Pounds of Milk Produced	Percent of Butterfat	Total Pounds of Butterfat
Sunflower Silage Period	4,778.5	3.56	169.97
Corn Silage Period	4,686.5	3.51	164.37
Difference in Favor of Sunflower Silage	92.0	.05	5.60

TABLE 10.—Weights of Cows in Second Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Weight at Beginning (Pounds)	Weight at End of First Period (Pounds)	Gain or Loss (—) in Weight During First Period (Pounds)	Weight at Beginning of Second Period (Pounds)	Weight at End of Second Period (Pounds)	Gain or Loss (—) in Weight During Second Period (Pounds)
GROUP 3	48	1117	1060	—57	1050	1080	30
	4	1514	1470	—44	1460	1460	00
	50	960	960	00	980	1000	20
	43	1025	980	—45	980	1030	50
	Total	4616	4470	—146	4470	4570	100
	Herd No. of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 4	47	1285	1180	—105	1240	1220	—20
	16	1510	1520	10	1490	1520	30
	52	678	700	22	680	700	20
	36	1170	1200	30	1190	1200	10
	Total	4643	4600	—43	4600	4640	40

TABLE 11.—Summary of Weights of Cows in Second Trial.

Feeding Periods and Difference	Weight of Cows at Beginning (Pounds)	Weight of Cows at End (Pounds)	Gain or Loss (—) in Weight (Pounds)
Sunflower Silage Period	9,216	9,110	—106
Corn Silage Period	9,113	9,170	57
Difference in Favor of Corn Silage			163

Bringing together the results of the two groups, Tables 9 and 11 show that the eight cows, while being fed sunflower silage during a 21 day period, produced 4778.5 pounds of milk, 169.97 pounds of butterfat, had an average butterfat test of 3.56 percent, and lost a total of 106 pounds in weight. The same eight cows, when fed corn silage, produced during the 21 days, 4686.5 pounds of milk, 164.37 pounds of butterfat, had an average butterfat test of 3.51 percent, and gained a total of 57 pounds in weight.

THE THIRD FEEDING TRIAL

In Trial III, each cow in Group 5 was fed 45 pounds of sunflower silage and each cow in Group 6 was fed 45 pounds of corn silage daily during the first four weeks of the trial. The rations were then changed so that the cows in Group 5 were fed corn silage and the cows in Group 6 were fed sunflower silage during the second four

weeks of the trial. Each cow in both groups was given eight pounds of alfalfa hay daily and one pound of grain for each 3.5 pounds of milk produced.

Tables 12, 13, 14, and 15 give the production of the different cows, their weights, a summary of the production of each group, and a summary of the weights of each group.

Tables 12 and 14 show that the five cows in Group 5, while being fed sunflower silage during a 21 day period, produced 2028 pounds of milk, 85 pounds of butterfat, and lost a total of 195 pounds in weight. The same five cows, when fed corn silage for a similar period, produced 1944.5 pounds of milk, 81.08 pounds of butterfat, and lost a total of 120 pounds in weight. The five cows in Group 6,

TABLE 12.—Production of Cows in Third Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Pounds of of Milk	Percent of Butterfat	Total Pounds Butterfat	Pounds of Milk	Percent of Butterfat	Total Pounds Butterfat
GROUP 5	107	304.6	5.16	15.71	292.8	5.42	15.86
	132	273.6	3.85	10.53	263.5	3.46	9.13
	106	236.9	5.23	12.40	255.8	4.95	12.66
	139	600.8	3.94	23.69	560.7	4.06	22.78
	138	612.1	3.70	22.67	571.7	3.61	20.65
	Total	2028.0	4.19	85.00	1944.5	4.17	81.08
	Herd No. of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 6	22	363.0	4.46	16.19	192.7	4.69	9.03
	89	233.8	3.93	9.18	169.8	4.20	7.14
	100	297.9	5.95	17.72	260.4	6.00	15.63
	137	672.1	4.17	28.01	544.4	4.30	23.41
	136	597.3	3.41	20.38	458.3	3.70	16.96
	Total	2164.1	4.23	91.48	1625.6	4.44	72.17

TABLE 13.—Summary of Production of Cows in Third Trial.

Feeding Periods and Differences	Pounds of Milk Produced	Percent of Butterfat	Total Pounds of Butterfat
Sunflower Silage Period	3,653.6	4.30	157.17
Corn Silage Period	4,108.6	4.20	172.56
Difference in Favor of Corn Silage	455.0		15.41
Difference in Favor of Sunflower Silage		0.10	

TABLE 14.—Weights of Cows in Third Trial.

	Herd Number of Cow	SUNFLOWER SILAGE			CORN SILAGE		
		Weight at Beginning (Pounds)	Weight at End of First Period (Pounds)	Gain or Loss (—) in Weight During First Period (Pounds)	Weight at Beginning of Second Period (Pounds)	Weight at End of Second Period (Pounds)	Gain or Loss (—) in Weight During Second Period (Pounds)
GROUP 5	107	990	990	00	990	970	—20
	132	1127	1070	—57	1077	1045	—32
	106	800	777	—23	795	800	5
	139	1150	1130	—20	1150	1087	—63
	138	1165	1070	—95	1075	1065	—10
	Total	5232	5037	—195	5087	4967	—120
	Herd No. of Cow	CORN SILAGE			SUNFLOWER SILAGE		
GROUP 6	22	1155	1130	—25	1165	1170	5
	89	865	870	5	875	880	5
	100	1005	1010	5	1010	1007	—3
	137	1090	1057	—33	1025	1080	55
	136	997	977	—20	977	970	—7
	Total	5112	5044	—68	5052	5107	55

TABLE 15.—Summary of Weights of Cows in Third Trial.

Feeding Periods and Difference	Weight of Cows at Beginning (Pounds)	Weight of Cows at End (Pounds)	Gain or Loss (—) in Weight (Pounds)
Sunflower Silage Period	10,284	10,144	—140
Corn Silage Period	10,199	10,011	—188
Difference in Favor of Sunflower Silage			48

when fed sunflower silage for a 21 day period, produced 1625.6 pounds of milk, 72.17 pounds of butterfat, and gained a total of 55 pounds in weight. The same five cows, when fed corn silage, produced 2164.1 pounds of milk, 91.48 pounds of butterfat, and lost a total of 68 pounds in weight.

Bringing together the results of the two groups, Tables 13 and 15 show that the ten cows, while being fed sunflower silage during a 21 day period, produced 3653.6 pounds of milk, 157.17 pounds of butterfat, had an average butterfat test of 4.3 percent, and lost a total of 140 pounds in weight. The same ten cows when fed corn silage produced 4108.6 pounds of milk, 172.56 pounds of butterfat, had an average butterfat test of 4.2 percent, and lost a total of 188 pounds in weight.

SUMMARY OF THE THREE FEEDING TRIALS

Tables 16 and 17 give a summary obtained by bringing the results of the three feeding trials together.

TABLE 16.— Summary of Production of the 28 Cows Used in the Three Trials.

Feeding Period and Difference	Total Pounds of Milk	Percent of Butterfat	Total Pounds of Butterfat
Sunflower Silage Period	14,295 9	3 83	547 05
Corn Silage Period	14,921.6	3 73	556.78
Difference in Favor of Corn Silage	625 7		9.73
Difference in Favor of Sunflower Silage		0.10	

TABLE 17.—Summary of Body Weights in the Three Trials.

Feeding Period and Difference	Weight at Beginning (Pounds)	Weight at) End (Pounds)	Loss in Pounds
Sunflower Silage Period	30,265	29,832	433
Corn Silage Period	30,047	29,816	231
Difference in Favor of Corn Silage			202

Table 16 shows that when twenty-eight cows were fed for a period of 21 days on sunflower silage, together with a basal ration of hay and grain, they produced 625.9 pounds of milk and 9.73 pounds of butterfat less than did the same twenty-eight cows when fed corn silage with the same basal ration for a period of similar length. Putting the results on a percentage basis, the groups fed sunflower silage produced 95.8 percent as much milk and 98.2 percent as much butterfat as did the groups fed corn silage. In all trials, the percentage of butterfat was slightly higher in the groups fed sunflower silage than in the groups fed corn silage. Table 17 shows that there was very little difference in the loss of weights of the cows when fed the different kinds of silage.

ANALYSES OF SUNFLOWERS

Samples were taken at different stages throughout one season from the time the sunflowers came into bud until they were mature. These samples were analyzed in order to determine their chemical composition at the various stages. The results of these analyses are given in Table 18.

These analyses, while limited in numbers, indicate that the sunflower plant does not reach its highest feeding value until about the dough stage. Results from the Illinois Station *(6)*, however, show that

TABLE 18.—Average Analyses of Sunflowers at Different Stages.

Stage Analyzed	Moisture (Percent)	Protein (Percent)	Carbohydrates (Percent)	Fiber (Percent)	Fat (Percent)	Ash (Percent)
Bud Stage	80 75	1.41	15.76	5.48	0 55	1.53
Full Blossom	86.69	1.21	10.01	3.90	0 50	1 59
Petals Dropping	83.97	1.12	12.47	5 56	0 66	1.78
Dough Stage	83.34	1.10	12 81	4.96	1 06	1.69
Mature	84.26	1.61	11.03	4.75	1 36	1 74
Silage	76 20	1.86	18.43	7.45	1.18	2 33

the sunflower plant becomes less palatable as it grows older, and that the best results were obtained when the crop was cut not later than the full blossom stage.

PALATABILITY OF SUNFLOWER SILAGE

In a few cases, in all of the groups, some of the cows refused to eat all of the sunflower silage at the beginning of the trial. All the cows, however, after they had been fed the sunflower silage for several days, ate it satisfactorily. They did not, however, seem to relish it as much as they did the corn silage.

There were no indications of ill health or digestive disarrangement from the feeding of sunflower silage. All the cows were in good health throughout the trials. The sunflower silage did not seem to be as laxative as the corn silage, but this was not noticeable to any great extent.

SUMMARY

The object of this investigation was to determine the relative feeding value of sunflower silage and of corn silage for the production of milk and butterfat, and for the maintenance of the weight of cows in milk.

Twenty-eight cows were used in the three trials. They were fed sunflower silage and a basal ration for a 21 day period, and corn silage plus a similar basal ration for another 21 day period. It was the plan, however, not to compare the two groups but rather to compare two feeding periods of the same group using one group as a check against the other.

Under the conditions of the experiment, the cows when fed sunflower silage produced 95.8 percent as much milk and 98.2 percent as much butterfat as they did when they were fed corn silage. In one trial, the cows when fed sunflower silage produced slightly more milk than they did when they were fed corn silage, but during the other two trials, the cows which were fed corn silage produced more milk. When the amounts of the silages fed were increased so that their effects would be more pronounced, the advantage of corn silage was increased.

The cows when fed sunflower silage maintained their weight almost as well as they did when they were fed corn silage.

Sunflower silage was slightly less palatable than corn silage, although most of the cows ate the sunflower silage very readily after they had become accustomed to it. Some of the cows, however, never did seem to relish it as well as they did corn silage.

In West Virginia, where sufficient good silage corn can be grown, there is no advantage in growing sunflowers for silage. In sections where sufficient corn cannot be grown, either because of short seasons or limited tillable acreage, the sunflowers will make a satisfactory substitute.

LITERATURE CITED

(1) BECHDEL, S. I.
1922. SUNFLOWER SILAGE FOR MILK PRODUCTION. Pa. Agr. Sta. Bul. 172.

(2) HICKS, W. H.
1924. CORN SILAGE VERSUS SUNFLOWER SILAGE. Report of the Superintendent, Agassiz, B. C., for the year 1923.

(3) JONES, ROY C.
1922. OATS AND VETCH VERSUS CORN OR SUNFLOWERS FOR SILAGE. Ore. Agr. Exp. Sta. Bul. 194.

(4) JOSEPH, W. E. and BLISH, M. J.
1920. STUDIES ON THE DIGESTIBILITY OF SUNFLOWER SILAGE. Montana Agr. Exp. Sta. Bul. 134.

(5) KNIGHT, C. S.
1918. SILAGE CROPS FOR NEVADA. Nev. Agr. Exp. Sta. Bul. 91.

(6) NEVENS, W. B.
1924. THE SUNFLOWER AS A SILAGE CROP. Ill. Agr. Exp. Sta. Bul. 253.

(7) QUESENBERRY, G. R., CUNNINGHAM, O. C., and FOSTER, L.
1921. THE CULTURE AND FEEDING OF RUSSIAN SUNFLOWERS. N. Mex. Agr. Exp. Sta. Bul. 126.

(8) SCHAFER, E. G. and WESTLEY, R. O.
1921. SUNFLOWER PRODUCTION FOR SILAGE. Wash. Agr. Exp. Sta. Bul. 162.

APPENDIX

Experimental Data Records

TABLE 19.—Production of Group 1 Fed Sunflower Silage and Group 2 Fed Corn Silage by Week Periods During First Feeding Period of First Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 1	22	180.6	4.3	7.765	165.9	3.8	6.304	173.3	4.3	7.452	164.2	3.8	6.240
	9	151.2	3.6	5.443	146.8	3.3	4.844	145.7	3.8	5.537	147.0	3.5	5.145
	21	200.5	3.8	7.619	182.4	3.6	6.566	189.4	4.0	7.576	166.8	3.4	5.671
	5	242.5	5.2	12.610	229.7	5.0	11.485	230.4	5.2	11.981	224.8	5.0	11.240
	17	291.5	3.6	10.494	289.5	3.4	9.843	299.6	3.3	9.887	287.2	4.0	11.488
	Average	213.3	4.12	8.786	202.9	3.85	7.808	207.7	4.09	8.486	198.0	4.02	7.957
GROUP 2	7	114.0	4.2	4.788	95.4	4.4	4.198	101.3	3.2	3.242	102.1	4.0	4.084
	6	235.4	3.5	8.239	233.3	3.1	7.232	241.4	3.2	7.725	217.7	3.2	6.966
	16	305.8	3.0	9.174	299.6	3.2	9.587	284.8	3.1	8.829	286.1	2.8	8.011
	23	227.4	3.3	7.504	238.3	3.0	7.149	234.0	2.9	6.786	220.4	3.0	6.612
	18	267.8	3.8	10.176	247.5	3.8	9.405	238.1	4.0	9.524	220.9	3.7	8.173
	Average	230.1	3.47	7.976	222.8	3.37	7.514	219.9	3.28	7.221	209.4	3.23	6.769

TABLE 20.—Production of Group 1 Fed Corn Silage and Group 2 Fed Sunflower Silage During Second Feeding Period of First Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 1	22	179.4	4.2	7.535	189.8	3.6	6.833	170.0	3.5	5.950	183.4	3.5	6.419
	9	140.3	3.0	4.209	140.8	3.1	4.365	127.7	3.0	3.831	128.6	3.6	4.630
	21	183.8	3.6	6.617	183.4	3.4	6.236	170.3	3.6	6.131	172.1	3.2	5.507
	5	216.6	4.8	10.397	212.0	6.3	13.356	205.1	5.5	11.280	195.6	5.5	10.758
	17	277.9	3.8	10.560	266.6	3.9	10.397	254.4	3.2	8.141	265.8	3.2	8.505
	Average	199.6	3.94	7.864	198.5	4.15	8.237	185.5	3.8	7.067	189.1	3.78	7.164
GROUP 2	7	87.1	3.4	2.961	92.5	4.6	4.255	91.2	4.1	3.739	100.2	4.2	4.208
	6	208.0	3.0	6.240	221.6	3.5	7.756	205.5	3.2	6.576	198.3	3.2	6.346
	16	264.6	3.4	8.996	252.3	3.1	7.821	253.9	3.2	8.125	253.7	3.1	7.865
	23	206.0	3.5	7.210	197.5	3.3	6.517	170.7	3.3	5.633	186.4	3.6	6.710
	18	205.1	4.1	8.409	196.0	4.0	7.840	211.7	3.8	8.045	189.6	3.8	7.205
	Average	194.2	3.48	6.763	192.0	3.56	6.838	186.6	3.44	6.424	185.6	3.48	6.467

TABLE 21.—Production of Group 3 Fed Sunflower Silage and Group 4 Fed Corn Silage During First Feeding Period of Second Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 3	48	149 4	3 70	5 528	139 3	3 65	5 084	132 9	3 55	4 718	137 0	3 60	4 932
	4	255 2	3 40	8 677	266 6	3 50	9 331	257 3	3 20	8 234	271 9	3 15	8 565
	50	234 6	4 35	10 205	216 5	4 25	9 201	194 1	4 35	8 443	198 9	4 00	7 956
	43	294 8	3 85	11 350	292 9	4 05	11 862	270 1	4 00	10 804	287 0	3 65	10 475
	Average	233 5	3 83	8 940	228 8	3 88	8 869	213 6	3 77	8 050	223.7	3 57	7 982
GROUP 4	47	188 5	3 60	6 786	183 7	3 60	6 613	192 9	4 35	8 391	181 7	3 50	6 359
	16	257 3	3 00	7 719	224 2	3 00	6 726	247 9	3 00	7 437	236 6	3 00	7 098
	52	146 3	4 15	6 071	147 1	4 15	6 105	130 8	3 95	5 167	124 2	4 10	5 092
	36	179 7	4 20	7 547	207 5	3 30	6 847	202 2	3 20	6 470	202 1	3 20	6 467
	Average	193.0	3 64	7 031	190 6	3 45	6 573	193 4	3 55	6 866	186 1	3 36	6 254

TABLE 22.—Production of Group 3 Fed Corn Silage and Group 4 Fed Sunflower Silage During Second Feeding Period of Second Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 3	48	139.8	3.20	4.474	152.4	3.40	5.182	148.4	3.30	4.897	142.8	3.50	4.998
	4	260.9	3.40	8.871	250.9	3.05	7.652	252.9	3.10	7.840	243.0	3.10	7.533
	50	185.2	4.25	7.871	177.3	4.35	7.713	171.6	4.40	7.550	160.4	4.60	7.378
	43	263.0	3.20	8.416	257.2	3.60	9.259	232.8	3.55	8.264	215.9	3.40	7.341
	Average	212.2	3.49	7.408	209.4	3.56	7.451	201.4	3.54	7.138	190.5	3.58	6.812
GROUP 4	47	164.6	3.55	5.843	180.0	3.20	5.760	178.8	3.20	5.722	166.3	3.30	5.488
	16	215.6	3.00	6.468	227.1	3.00	6.813	242.7	3.05	7.402	223.7	2.80	6.264
	52	112.1	4.55	5.100	119.8	4.55	5.451	115.7	4.35	5.033	102.2	4.30	4.395
	36	190.1	3.25	6.178	191.0	3.30	6.303	188.1	3.20	6.019	178.6	3.20	5.715
	Average	170.6	3.46	5.897	179.5	3.39	6.082	181.3	3.33	6.044	167.7	3.26	5.465

TABLE 23.—Production of Group 5 Fed Sunflower Silage and Group 6 Fed Corn Silage During First Feeding Period of Third Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 5	107	115.3	5.6	6.457	97.2	5.6	5.443	103.9	5.3	5.507	103.5	4.60	4.761
	132	103.2	3.9	4.025	91.7	3.9	3.576	90.3	4.0	3.612	91.6	3.65	3.343
	106	92.1	5.6	5.158	78.1	5.4	4.217	81.4	5.2	4.233	77.4	5.10	3.947
	139	243.1	4.0	9.724	215.5	3.8	8.189	204.4	4.0	8.176	180.9	4.05	7.326
	138	247.3	3.9	9.645	217.8	3.7	8.059	207.5	3.8	7.885	186.8	3.60	6.725
	Average	160.2	4.37	7.002	140.06	4.21	5.897	137.5	4.28	5.883	128.04	4.08	5.220
GROUP 6	22	150.7	4.4	6.631	133.0	4.4	5.852	119.1	4.4	5.240	110.9	4.20	5.101
	89	86.9	4.0	3.476	79.9	3.7	2.956	78.9	3.9	3.077	75.0	4.60	3.150
	100	112.4	6.0	6.774	101.2	5.7	5.768	100.9	6.2	6.256	95.8	5.95	5.700
	137	270.2	4.1	11.078	254.5	4.2	10.689	218.0	4.1	8.938	199.6	4.20	8.383
	136	223.6	3.4	7.602	207.4	3.4	7.052	201.5	3.2	6.448	188.4	3.65	6.877
	Average	168.76	4.21	7.112	155.2	4.16	6.463	143.68	4.17	5.992	133.94	4.36	5.842

TABLE 24.—Production of Group 5 Fed Corn Silage and Group 6 Fed Sunflower Silage During Second Feeding Period of Third Trial.

	Herd No. of Cow	Preliminary Week			First Week			Second Week			Third Week		
		Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat	Pounds Milk	Percent Fat	Pounds Fat
GROUP 5	107	101.4	4.80	4.867	97.8	5.3	5.183	100.1	5.40	5.405	94.9	5.55	5.267
	132	90.1	3.70	3.333	92.4	3.4	3.142	90.3	3.50	3.160	80.8	3.50	2.828
	106	80.4	5.05	4.060	87.5	4.8	4.200	84.2	5.05	4.252	84.1	5.00	4.205
	139	191.2	3.90	7.457	207.3	3.9	8.085	181.6	4.50	8.172	171.8	3.80	6.528
	138	199.3	3.60	7.175	213.9	3.7	7.914	189.2	3.70	7.000	168.6	3.40	5.732
	Average	132.48	4.06	5.378	139.78	4.08	5.705	129.08	4.34	5.598	120.04	4.09	4.912
GROUP 6	22	92.5	3.60	3.330	73.7	4.6	3.390	62.7	4.95	3.104	56.3	4.50	2.533
	89	64.6	3.60	2.326	58.8	4.2	2.470	59.1	4.25	2.512	51.9	4.15	2.154
	100	90.4	6.00	5.424	89.1	6.0	5.346	88.4	6.10	5.392	82.9	5.90	4.891
	137	199.9	4.20	8.396	194.1	4.3	8.346	178.8	4.30	7.688	171.5	4.30	7.374
	136	168.0	3.05	5.124	157.6	3.7	5.831	154.3	3.70	5.709	146.4	3.70	5.417
	Average	123.08	4.00	4.920	114.66	4.43	5.077	108.66	4.49	4.881	101.8	4.39	4.474

Bulletin 211 December, 1927

Agricultural Experiment Station
College of Agriculture, West Virginia University
N. J. Giddings, Acting Director
Morgantown

A Study of the Hardiness of the Fruit Buds of the Peach

[TECHNICAL]

By

H. E. KNOWLTON and M. J. DORSEY

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D.................................President of the University
N. J. GIDDINGS, Ph. D...Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr...Agricultural Editor
JOHN C. JOHNSTON...Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S **
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*A Study of the Hardiness of the Fruit Buds of the Peach**

Winter killing of the fruit buds of the peach in West Virginia is a serious limiting factor to an otherwise profitable crop. In some sections a crop failure from this cause alone may occur as often as two or even three times in a five-year period. This problem has been given considerable study in the peach-growing regions of other states, and may be considered as separate and distinct from that of the injury to flowers and young fruits by spring frosts. In this investigation, in West Virginia, attention has been given to the following points: (a) the relative hardiness of the fruit buds of some of the more important varieties, (b) the stages of development in the fruit bud throughout the season, and (c) the influence of culture and fertilizers upon fruit-bud hardiness. These three phases of the subject will be taken up in the order named.

The wood of the varieties under observation in this study was found to be injured less frequently than the fruit buds. During the winter of 1924-25 some wood injury occurred, but as far as observations were made, only young or rapidly growing trees were affected. When winter conditions in this state kill all the fruit buds, there may also be some killing of the wood. It rarely happens in this latitude that the fruit buds prove to be hardier than the wood, although an instance of this condition was reported in Ohio by Thayer *(1916)*. The fruit buds, therefore, may be regarded as a more sensitive index to hardiness than the wood.

SOME EFFECTS OF WINTER CONDITIONS IN WEST VIRGINIA

The problem of fruit-bud hardiness with the peach, Japanese plum, and sweet cherry is apparently more important in the latitude of West Virginia than it is farther north. This is because of the mild winters with frequent periods of warm weather. Figure 1 shows daily maximum and minimum temperatures for the winter of 1921-1922. It will be seen in this figure that maximum temperatures were above 50° F. eight times and above 60° three times during December, January, and February. On February 25 the temperature was 75° F. These warm

*Submitted for publication May, 1926.

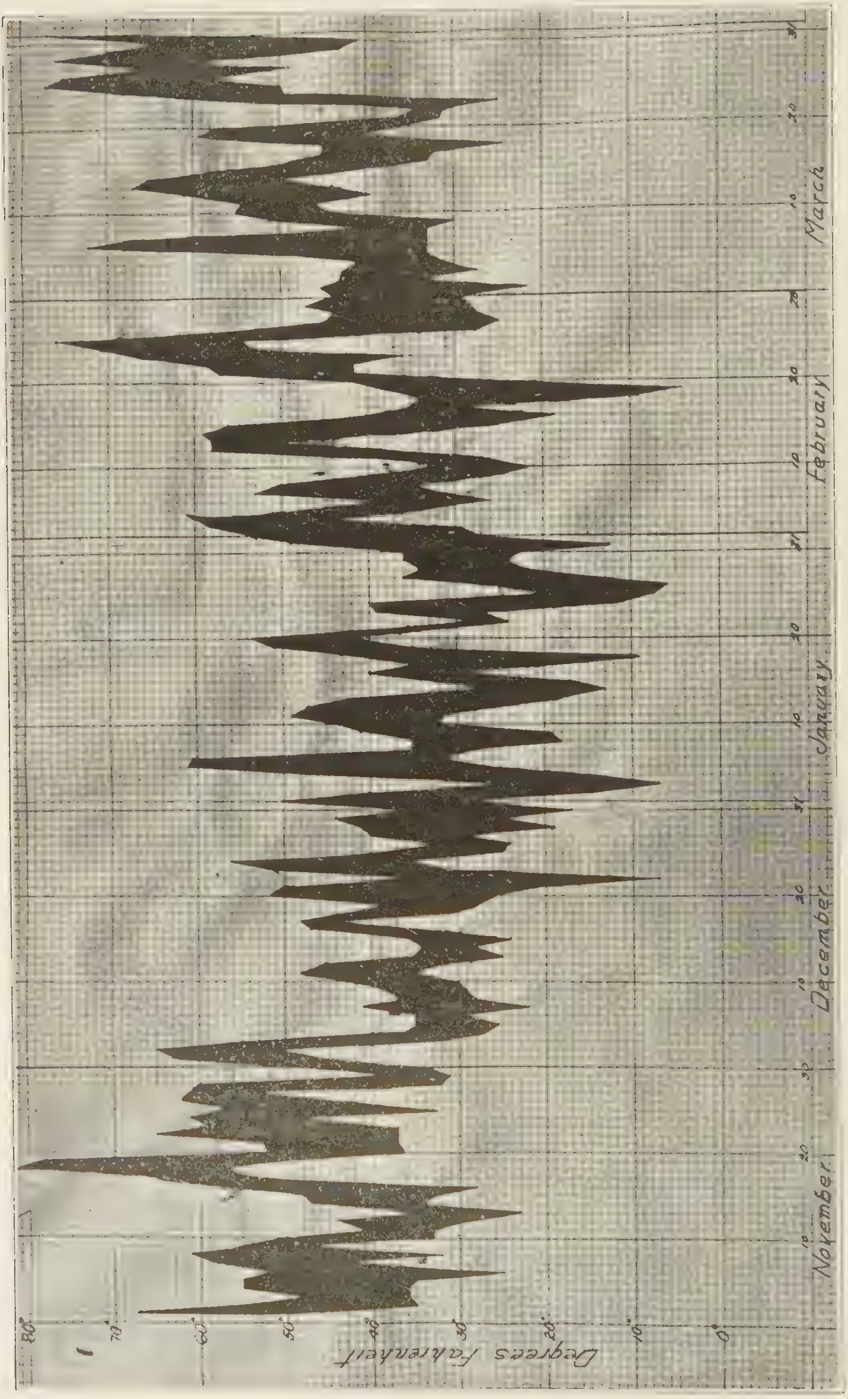


Fig. 1.—Maximum and minimum temperatures, winter of 1921-22, Morgantown, West Virginia.

spells, if they occur toward the end of the rest period in early January and later, start buds into growth. This brings about a marked decrease in their resistance to subsequent low temperatures. In the winter of 1924-1925 almost all fruit buds on the tender and semi-hardy varieties of peach in the Experiment Station Orchard were killed by a sudden drop in temperature to —9° F., following a period of warm weather in late January. In the northern peach sections of New York, Michigan, and Ontario, where warm periods seldom occur during winter, peach buds have withstood temperatures as low as —20° F. without injury. This extreme resistance, however, is only shown at the end of long cold periods.

VARIETAL DIFFERENCES IN THE HARDINESS OF FRUIT BUDS

It is generally recognized by peach growers that the fruit buds of some varieties are hardier than those of others. This condition has been given some study in West Virginia, and in this latitude significant differences were found when a survey was made of some of the more important varieties.

In the spring of 1923 the condition of all of the fruit buds on two hundred nodes, each of some of the more important commercial varieties under test in the Experiment Station variety orchard, was studied. This classification was made at the pink stage, but before the winter-killed fruit buds had fallen. At this time the winter-killed fruit buds could easily be distinguished from those not killed, by differences in size. A study of Table 1 will show interesting differences in the effect of winter temperatures on the different varieties.

While there was considerable killing in all of the varieties, some of them like Reeves, Nectar, and Bilmeyer lost nearly all of their fruit buds from winter killing. The contrast between these and Belle, Burton, Greensboro, or Hiley, in the number of fruit buds or flowers surviving the winter, is noticeable. An interesting feature of the killing in this season was the large number of dead pistils in some varieties. This conditon appeared to be peculiar to this season, in view of the fact that only an occasional dead pistil could be found the following season.

Death was apparently due to occurrence of low temperature after considerable growth had taken place. This indicates that the pistil is more susceptible to injury at certain stages of growth than are the other parts of the flower. When only the pistil is killed, bloom occurs in an apparently normal manner, but the flowers drop a few days after opening. Pistil injury was especially noticeable in Carman and Late

TABLE 1.—Fruit Bud Condition on Selected Commercial Varieties of Peach Following the Winter of 1922-1923.

Variety	Total Number of Fruit Buds on 200 Nodes	Percent of Winter-Killed Fruit Buds	Percent of Flowers with Dead Pistils	Percent of Flowers with Live Pistils
Belle	301	25.6	8.0	66.4
Bilmeyer	118	88.1	5.1	6.8
Burton	300	25.0	1.0	74.0
Carman	242	6.2	34.7	59.1
Champion	151	65.5	4.6	29.9
Crawford Late	155	0.0	84.5	15.5
Early Elberta	162	52.4	0.6	47.0
Elberta	176	47.2	8.5	44.3
Greensboro	306	8.2	3.9	87.9
Hiley	273	20.5	10.6	68.9
J. H. Hale	137	68.6	0.7	30.7
Nectar	59	84.7	5.1	10.2
Reeves	57	100.0	0.0	0.0
Rochester	71	35.2	2.8	62.0
Salwey	167	59.3	5.4	35.3

Crawford. It will be seen, then, that at bloom, all the fruit buds produced in the fall can be grouped into three categories as listed in Table 1. It is evident that the crop must be obtained from the flowers with live pistils. A similar classification in other years may show a marked difference in the grouping of the buds under the different headings of this table.

The study of the relative hardiness of fruit buds on the terminal growths and on the shorter lateral growths on the interior of the tree discloses some interesting differences. The data on this point are summarized in Table 2.

As before, the buds on 200 nodes were made the basis of comparison. Fruit-bud production was relatively heavy the year that these counts were made, and marked differences were found between varieties. The varieties also varied considerably in the percentages of fruit buds killed. In Belle and Crawford, there was slightly less killing of buds on the inner lateral growths than of those on the outer terminal growths. Elberta, on the other hand, showed considerably more killing on the short lateral growths on the inner part of the tree. Rochester was in the same category, but not so pronounced. It is possible that, if larger numbers of fruit buds of these varieties had been counted, different results would have been obtained.

In making these counts of killed buds, attention was not given to the relative hardiness of buds borne on the basal, median, and terminal parts of the longer outer growths. Observations, however, during the

TABLE 2.—The Relative Hardiness of Fruit Buds Borne on Short and Long Growths During the Season of 1923-1924.

Variety	Trees	Spurs or Laterals Less Than 3½ Inches in Length			Outside Terminal Growths 16 to 20 Inches Long			Percent Fruit Buds Killed on Short Growths	Percent Fruit Buds Killed on Terminals
		Number of Nodes	Number of Flowers Alive	Number of Fruit Buds Winter-Killed	Number of Nodes	Number of Flowers Alive	Number of Fruit Buds Winter-Killed		
Belle	1	200	107	51	200	65	106	32	62
	2	200	99	70	200	69	110	41	61
	3	200	168	99	200	93	122	37	57
	4	200	126	102	200	95	73	45	43
Late Crawford	1	100	24	81	200	14	128	77	90
	2	200	21	163	200	8	166	89	95
	3	200	20	184	200	8	125	90	94
	4	200	29	181	200	19	139	86	88
Elberta	1	200	37	142	200	44	31	79	41
	2	200	44	146	200	16	19	77	54
	3	200	35	141	200	17	20	80	54
Rochester	1	200	127	73	200	91	50	37	35
	2	200	110	114	200	118	59	51	33
	3	200	106	97	200	92	51	48	36
	4	200	109	43	200	98	55	28	36

winter of 1924-25 showed that the few buds still alive were either on "spurs" or on the base of terminals. Chandler *(1908)* found that some of the hardiest buds on the tree were borne at the base of the terminal growths. It will be shown later that the buds in this position lag behind the others in development during winter and come into bloom more slowly in the spring.

In the studies of the relative hardiness of some of the more important varieties in the eastern and western parts of the state, the data in Table 3 were obtained. The records cover three years at Morgantown, two at Mason City and at Metz, but only one year at the other locations. Sixteen varieties in all are included in the table. Fruit buds were counted on from 200 to 700 nodes.

The percentages of the fruit buds killed each year at Morgantown and at Metz were relatively large, although one-fourth of the fruit buds, or even fewer, would be ample for a full crop if all were to set fruit. When the percentage of fruit buds killed at Morgantown and at Metz during 1923-24 is compared by varieties with the fruit-bud killing at points east of the mountains, it is evident that there is much

TABLE 3.—Varietal Differences in Percent of Fruit Buds Killed in Different Locations in West Virginia.

VARIETIES	LOCATIONS AND YEARS												
	Ruttencutter Orchard Mason City		Horticultural Farm Morgantown			Homer Campbell Orchard Metz, Marion County		E. A. Leatherman Orchard Rada, Hampshire County	Cecil Woods Back Creek Orchard Company Berkeley County	M. W. Fulton Orchard Cherry Run, Morgan County	Reed Butts Orchard Morgan County	Ernest McDonald Orchard Inwood, Berkeley County	Smith Orchard Martinsburg, Berkeley County
	1923-24	1924-25	1922-23	1923-24	1924-25	1923-24	1924-25	1915-16	1923-24	1923-24	1923-24	1923-24	1923-24
Belle		52	34	51	95	88	68	70	2	6	5	10	72
Bilyou				48	88			50					
Carman	28	38	40	33	92	44	70	20	2	4	3		
Champion	68	58	68	65	89	46	93	80	6		6	21	
Early Elberta			53	88	100								
Elberta	55	95	56	74	100	81	100	98	5	6	10	12	66
Fox		95		69	99			99					
Hiley			31	77	99			99	10		6		
J. H. Hale			70	91	100			89			84	35	
Krummel					92			60					
Late Crawford	64	95	85	87	100			90					
Mayflower				25	74			50					
Reeves			100	100	100			100	7				
Rochester			38	44	94								
Salwey	29	24	65	46	95	44	86	60		16	10		
Smock		63						70		5			

less injury in the eastern counties. This is probably due to the more uniform temperatures that prevail there.

The records of Belle and Elberta in the Smith orchard near Martinsburg may appear exceptional, but the bud killing in this instance was determined from young trees which had grown until relatively late the previous season. There was but little difference between the percent of the fruit-bud killing in the Butts orchard, with young trees, and in the Woods and Fulton orchards, with older trees. The trees in the Experiment Station and Metz orchards were about seven years old in 1925.

It is interesting to note the bud killing each year in Reeves as compared with some of the other varieties. Blake and Connors *(1918)* found that varieties like Reeves, Early Crawford, Late Crawford, and Mountain Rose are much more susceptible to fruit-bud injury than Greensboro, Carman, and Belle. Elberta and J. H. Hale have also been injured extensively in the West Virginia Experiment Station orchard. There was a complete loss in a number of varieties in the same orchard in the winter of 1924-25. During the same winter, in the eastern part of the state, the killing of fruit buds appeared to be somewhat variable, some orchards coming through the winter with relatively light injury, while others near by were severely injured. Spring frosts, however, soon after bloom, killed practically all the flowers remaining after the winter killing.

The greater hardiness of the fruit buds of some varieties may have considerable significance when measured by yield. Chandler *(1908)* says that if only three to ten percent of the fruit buds were to set, there would be enough to produce a full crop of fruit. In 1906 he found that peach trees, with 90 percent of their fruit buds killed, set a good crop of fruit. Blake and Farley *(1911)* observed that experienced fruit growers are generally satisfied if one-half of the fruit buds survive the winter and early spring. It is evident, however, that with only a small percentage of the fruit buds surviving the winter or early spring low temperatures, a crop will depend very largely upon favorable weather conditions at pollination time.

In stressing the influence of regularity of bearing upon profitable peach growing, Odell *(1924)* writes regarding a test of twenty-five varieties, in which five to twenty trees of each were planted: "Planted in 1916, these trees bore a fair crop in 1919, and heavy crops in 1920, 1922, and 1924. Such hardy varieties as Carman, Greensboro, and Mayflower bore well in 1923, also doubled the production of other varieties in 1919, making five crops against three and one-half for

most of the others.'' Differences in the relative hardiness of the fruit buds may, therefore, have a far-reaching influence upon fruit production. Unfortunately, however, when consideration is given to the selection of varieties on the basis of the hardiness of the winter bud, other factors must be taken into consideration. The outstanding fact of the peach situation is the dominance of Elberta, which is one of the tenderest varieties as measured by fruit-bud killing. Local conditions and market preference must determine whether it is safe to consider substituting other varieties, wholly or in part, for Elberta.

GROWTH AND DEVELOPMENT OF FRUIT BUDS DURING DORMANT SEASON

All of our deciduous fruit trees normally have an annual period when their tops do not grow perceptibly even if environmental conditions are favorable. This is commonly called the ''rest period.'' It comes on gradually soon after terminal buds are formed in late summer or early fall and continues until some time in winter, the length of the period depending on the kind of fruit. During December, in the case of the peach, the rest becomes less profound, and the fruit buds start growing if weather conditions are favorable. This gradual breaking of the rest period of Elberta, Rochester, and Belle for the season of 1921-22 is clearly shown in Table 4.

Branches from three trees of each variety were taken to the greenhouse on the dates stated in the table and placed in water. The time elapsing before blossoms opened on these branches was used as an index of the condition of rest. All the varieties were coming out of the rest period by January 3, and as the season advanced all responded more rapidly to the favorable conditions of the greenhouse. No branches were taken to the greenhouse in the period between December 1 and January 3, consequently, the bloom tests do not show just when the break occurred. In the winter of 1922-23, branches brought in on December 12, bloomed January 9. Hodgson *(1924)* found that the rest period of the peach ended in California by January 9 to January 26. In Missouri, according to Howard *(1910)*, the peach grew readily as early as January 8. Johnson *(1923)* reported similar results in Maryland.

Table 4 also shows that Elberta seemed to have a slightly shorter rest period than either Rochester or Belle. This corroborates the observations of Blake *(1916)*, who says that in the winter of 1915-16 there was a good set of fruit buds in one orchard, and that during January ''a period of extremely warm weather started the buds to

TABLE 4.—The Break in the Rest Period as Indicated by Date of Bloom of Cut Branches Kept in Water in Greenhouse (1921-1922).

Varieties	Dates Cut Branches Were Taken to Greenhouse	Dates of Bloom	Number Days Before Bloom	Remarks
Elberta	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Rochester	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Belle	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Elberta	Dec. 1			Fruit buds dried up.
Rochester	Dec. 1			Fruit buds dried up.
Belle	Dec. 1			Fruit buds dried up.
Elberta	Jan. 3	Jan. 20	17	Center and apical buds opened first.
Rochester	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
Belle	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
Elberta	Jan. 19	Feb. 2	14	All buds opened.
Rochester	Jan. 19	Feb. 8	20	All buds opened.
Belle	Jan. 19	Feb. 8	20	All buds opened.
Elberta	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Rochester	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Belle	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Elberta	Feb. 20	Mar. 2	10	Center and apical buds first.
Rochester	Feb. 20	Mar. 2	10	Center and apical buds first.
Belle	Feb. 20	Mar. 2	10	Center and apical buds first.
Elberta	Mar. 3	Mar. 14	11	Center and apical buds first.
Rochester	Mar. 3	Mar. 14-15	12	Center and apical buds first.
Belle	Mar. 3	Mar. 14-15	12	Center and apical buds first.
Elberta	Mar. 13	Mar. 20	7	Center and apical buds first.
Rochester	Mar. 13	Mar. 22	9	Center and apical buds first.
Belle	Mar. 13	Mar. 20-21	8	Center and apical buds first.
Elberta	Mar. 25	Mar. 29	4	
Rochester	Mar. 25	Mar. 29	4	
Belle	Mar. 25	Mar. 29	4	

swell." He also observed that the same season "gave further evidence that Elberta and other varieties of its group, such as Early Elberta and J. H. Hale, start into growth upon the occurrence of the first warm days of winter and are later injured by cold. On the other hand, varieties like Carman and Greensboro, which respond less quickly to periods of warm weather, escaped with slight loss." Strausbaugh *(1921)* found in studying three varieties of plums that the one which would withstand the lowest temperature also had the longest and most profound rest period. Pojarkova *(1924)* found a similar correlation with species of Ribes, but not with those of Acer and Berberis. Strausbaugh also noted that during the rest period the

moisture content of the fruit buds of the semi-hardy plum varieties fluctuated with the temperature. In contrast the moisture content of a hardy variety, Assiniboine, remained fairly constant. Johnson *(1923)* found that moisture contents of buds of several varieties of peach were negatively correlated with bud hardiness.

Undoubtedly, the extent and the degree of rest influence hardiness by delaying the response of the buds to temperatures that usually bring about growth. As has been shown, warm spells are of frequent occurrence during the winter months in West Virginia, particularly in the territory west of the Alleghenies. The peach, with its rest period soon over, responds to these favorable growing temperatures of mid- and late winter, and then, if the weather becomes very cold later, is injured. On the other hand, the apple, with a long, deep rest period, is not influenced so much by these temperatures. This is probably one of the causes for its remarkable bud hardiness during winter.

POLLEN DEVELOPMENT

Although outwardly no apparent growth takes place during the rest period, development within the fruit bud continues. Flower parts form and enlarge, and by the end of the rest period in January, most of them can be easily distinguished. The time that perceptible cell differentiation began in pollen and ovules following the rest period, and the extent of their development at successive dates during the dormant season, were taken as indices of the changes going on within the fruit bud. Considerable study was given to the differentiation and growth of the fruit buds during the winters of 1921-22 and 1922-23. Fruit buds were collected at intervals from trees of each of the three varieties, Elberta, Rochester, and Belle. Buds were selected separately as follows: (1) from short growths up to 3½ inches in length from the inside of the tree, and (2) from long outside terminal growths, 12 to 24 inches in length, or more. Buds prepared for study from the long branches were further classified into three lots—those from basal, median, and terminal positions on the branch. In the winter of 1922, collections of buds were also made from laterals on the long growths. The material was killed immediately in one percent chromo-acetic acid, imbedded in paraffin, sectioned, and stained in either Haidenhain's or Fleming's Triple stain.

The stages in the development of pollen at the different dates of collection are shown in Tables 5 to 9, inclusive:

TABLE 5.—Stages in Development of Pollen of "Elberta" During Winter of 1921-1922.

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED

STAGES IN POLLEN GROWTH	November 8				December 1				January 3				January 19				February 9			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																				
Mature pollen																				
Two nuclei, dense cytoplasm																				
Two nuclei, scant cytoplasm																				
One nucleus, thick wall																				
One nucleus, thin wall																				
Germ pores forming																				
Microspores liberated																1			1	3
Late tetrads																				
Early tetrads																	7		1	4
Diads																	3	1		
Reduction division													2				1	3	1	
Diakenesis																			1	
Open spireme												1	2	2	6	4		2		
Synapsis									2	1	2	3	3	5	7	2		2		
Pollen mother-cell					9	5	9	5	4	15	12	3	3	4	2	1				
Early pollen mother-cell					2	3	6	3												
Archesporial cells	8	9	12	3	2															

STAGES IN POLLEN GROWTH	February 20				March 3				March 13				March 25				April 4			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																	3	2	4	
Mature pollen												2	3	3	7	5			2	
Two nuclei, dense cytoplasm											3		2		3	1			1	
Two nuclei, scant cytoplasm									7	4	10	5			4	1			1	
One nucleus, thick wall	2				6	4	8	2	1											
One nucleus, thin wall	1	1		2			1			1										
Germ pores forming																				
Microspores liberated	1		2		1			1												
Late tetrads			3	1																
Early tetrads	3	6	4					2												
Diads		1																		
Reduction division																				
Diakenesis																				
Open spireme																				
Synapsis																				
Pollen mother-cell																				
Early pollen mother-cell																				
Archesporial cells																				

TABLE 6.—Stages in Development of Pollen of "Elberta" During Winter of 1922-1923.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED																															
	October 2				November 1				December 12				January 9				February 2				February 20				March 12				March 26			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																															1	3
Mature pollen																											1		4	2	1	
Two nuclei, dense cytoplasm																											4	1				
Two nuclei, scant cytoplasm																											8		1			
One nucleus, thick wall																						2	1	7		5						
One nucleus, thin wall																				2				1								
Germ pores forming																								1								
Microspores liberated																			4	3				1								
Late tetrads																			5	2		2	1	1								
Early tetrads																		4	5	2			1									
Diads																																
Reduction division															1			2	1													
Diakenesis															1																	
Open spireme															5	3																
Synapsis														4	3	2		1														
Pollen mother-cell											5	6																				
Early pollen mother-cell										1	9																					
Archesporial cells						3			1	8																						
Pre-archesporial cells	1		4	2		3	9	1																								

TABLE 7.—Stages in Development of Pollen of "Rochester" During Winter of 1921-1922.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED																																							
	November 8				December 1				January 3				January 19				February 9				February 20				March 3				March 13				March 25				April 4			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																																					2		1	2
Mature pollen																																				3		2		
Two nuclei, dense cytoplasm																																	4	2	2					
Two nuclei, scant cytoplasm																														1			7	8	1	3				
One nucleus, thick wall																													12	4	6	9			1					
One nucleus, thin wall																									8			4	1	1	2									
Germ pore forming																									4	1	4	1												
Microspores liberated																									2	1	1	2												
Late tetrads																							1	1		7	3													
Early tetrads																			1				2			2														
Diads																				1			1	1																
Reduction division																			1							1														
Diakenesis																										1														
Open spireme																	1				6	3		1																
Synapsis													3		8	4	6	1	4		1	5	4																	
Pollen mother-cell						2		1	19	17	9	8	12	17	8	2	2	12				1																		
Early pollen mother-cell					6	15	8	3																																
Archesporial cells	8	4	6	5																																				

TABLE 8.—Stages in Development of Pollen of "Belle" During Winter of 1921-1922.

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED

STAGES IN POLLEN GROWTH	November 8				December 1				January 3				January 19				February 9			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																				
Mature pollen																				
Two nuclei, dense cytoplasm																				
Two nuclei, scant cytoplasm																				
One nucleus, thick wall																				
One nucleus, thin wall																				
Germ pore forming																				
Microspores liberated																				
Late tetrads																				
Early tetrads																				
Diads																				1
Reduction division																				
Diakenesis																	1			
Open spireme	3												1							4
Synapsis												2	4	1	11	6	18	7	9	3
Pollen mother-cell					1	2		2	8	1	11	3	11	14	3		5	8		
Early pollen mother-cell					16	12	12	12	12	10	5	1								
Archesporial cells	15	9	8	5																

STAGES IN POLLEN GROWTH	February 20				March 3				March 13				March 25				April 4			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																	2	2	2	2
Mature pollen													4		7	6	1			
Two nuclei, dense cytoplasm									4		4		6	6	5	1				
Two nuclei, scant cytoplasm									17	4	3	1	3	5	1					
One nucleus, thick wall					11	4	4	9		9	6	8			3					
One nucleus, thin wall					4	3	5	4			3	1								
Germ pore forming					2	6														
Microspores liberated				3			3													
Late tetrads	4		6	7	1															
Early tetrads	4	4	4	2																
Diads	1	1	1																	
Reduction division	1	3																		
Diakenesis	2	3																		
Open spireme	3	1																		
Synapsis																				
Pollen mother-cell																				
Early pollen mother-cell																				
Archesporial cells																				

TABLE 9.—Stages in Development of Pollen of "Belle" During Winter of 1922-1923.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED																															
	October 2				November 1				December 12				January 9				Feburary 2				February 20				March 12				March 26			
	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds	Short Spur Buds	Long Shoots, Basal Buds	Long Shoots, Median Buds	Long Shoots, Terminal Buds
Resting pollen																													6		2	2
Mature pollen																													5	1	5	3
Two nuclei, dense cytoplasm																											3	1	1	1	4	3
Two nuclei, scant cytoplasm																											2		1		1	
One nucleus, thick wall																									6	3	9	5				
One nucleus, thin wall																										1						
Germ pores forming																							2		2							
Microspores liberated																																
Late tetrads																		2	2			2	9	7	1							
Early tetrads																		4	8			4										
Diads																		1	1				2									
Reduction division																		1	5				1									
Diakenesis																		1	5	7		1										
Open Spireme																				1												
Synapsis															5	7				3		3										
Pollen mother-cell												1		5	12	1						1										
Early pollen mother-cell											11	6																				
Archesporial cells					3		5	3	3	8	8																					
Pre-archesporial cells		4	6	3	1		5								1																	

Since some buds showed quite a range in degree of development of pollen, the most advanced stage, which is the one recorded, was determined for each flower bud. Development of pollen at the different dates was not so advanced as that observed by Drinkard *(1909)* in Virginia for the variety Luster. He found pollen mother-cells early in November, tetrad formation on December 19, and pollen grains on January 18. Farr *(1920)* also found a more advanced stage of pollen development, than that recorded in these studies, with a number of varieties growing at different places in West Virginia, Maryland, Virginia, and New Jersey. When pollen growth during the winter of 1921 is compared with growth during the winter of 1922, there are, in general, no marked differences to be observed. If, however, collections had been made on the same dates each year, perhaps some differences would be shown.

All varieties show a great range in pollen development, especially from February until April—(Tables 10 to 11). Thus on February 9, 1922 (Table 10), two out of 30 buds of Elberta show pollen mother-cells in synapsis while four buds have liberated microspores. On January 9, 1923, one Elberta bud had not yet formed archesporial cells (Table 11). Drinkard *(1909)* found some pollen mother-cells still in the tetrad stage at the end of January, although in most buds pollen grains had been formed. The studies of Farr *(1920)* also show considerable range in development at the different dates that collections were made. At nearly every collection, Elberta buds showed a wider range in development than did buds of Belle and Rochester. This undoubtedly indicates a greater sensitivity to environmental factors, or, in other words, a less profound rest period.

Both Table 10, for the winter of 1921, and Table 11, for the winter of 1922, show Elberta buds to be further advanced by early January than those of Belle or Rochester. Rochester buds seem to develop somewhat more slowly than do buds of Belle. Farr *(1920)* found that, during January, Elberta and Champion buds were the most advanced, with Belle buds the farthest behind and Carman buds intermediate.

These studies also show the relation that exists between the stage of pollen development, and (a) the position of the bud upon the twig, and (b) the length of the twig (Tables 5 to 9). Differences in development in the pollen mother-cells became more pronounced during synapsis, in the early part of January. At this time the pollen from the majority of the terminal and median buds had forged ahead in development. Basal buds apparently did not catch up until the

TABLE 10.—Range in Pollen Development in "Elberta," "Rochester," and "Belle" During Winter of 1921-1922.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND VARIETIES STUDIED																													
	November 8			December 1			January 3			January 19			February 9			February 20			March 3			March 13			March 25			April 4		
	Elberta	Rocehester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle	Elberta	Rochester	Belle
Resting pollen																												9	5	8
Mature pollen																						2			18	3	17	2	2	1
Two nuclei, dense cytoplasm																						3		8	6	8	18	1		
Two nuclei, scant cytoplasm																						26	1	25	5	19	9	1		
One nucleus, thick wall																2			20		28	1	31	23		1	3			
One nucleus, thin wall																4			1	12	16	1	4	4						
Germ pore forming																				10	8									
Microspores liberated										1			4			3		3	2	6	3									
Late tetrads																4	2	17		10	1									
Early tetrads													12	1		13	2	14	2	2										
Diads													4	1	1	7	2	3												
Reduction division										2			5	1				4		1										
Diakensis													1		1			5		1										
Open spireme	3						1			14		1	2	1	4	2	10	4												
Synapsis									2	17	15	22	2	11	37		10													
Pollen mother-cell				28	3	5	8	53	23	10	39	28		14	13		1													
Early pollen mother-cell				14	32	52	34		28																					
Archesporial cells	32	23	37	2																										

TABLE 11.—Range in Pollen Development in "Belle" and "Elberta" During Winter of 1922-1923.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND VARIETIES STUDIED															
	October 2		November 1		December 12		January 9		February 2		February 20		March 12		March 26	
	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta
Resting pollen															10	6
Mature pollen														1	14	5
Two nuclei, dense cytoplasm													3	5	8	
Two nuclei, scant cytoplasm													3	8	2	1
One nucleus, thick wall												10	23	6		
One nucleus, thin wall										2		1	1			
Germ pore forming											2	1	2			
Microspores liberated										7		1				
Late tetrads									4	7	18	4	1			
Early tetrads									12	11	4	1				
Diads									2		2					
Reduction division								1	6	3	1					
Diakenesis								1	13		1					
Open spireme								9	1							
Synapsis							12	13	3	1	3					
Pollen mother-cell					7	12	18			1	1					
Early pollen mother-cell					17	9										
Archesporial cells			11	3	19	10										
Pre-archesporial cells	13	7	6	13		2		1								

pollen was near maturity. Pollen from most of the buds on the short inside "spurs" maintained a position intermediate between pollen from basal and median buds on the longer growths. Placing the buds from the different positions on the tree according to the average degree of pollen development during January and February, the following order is found: (1) the terminal buds on outside shoots 12 inches or more in length, (2) the median buds from the same shoots, (3) buds from short inside "spurs" up to six inches in length, and (4) basal buds from the long outside shoots. Since fruit-bud initiation is known to begin first on the basal portions of shoots, the rate of development of median and terminal buds must be faster in order that they be farther advanced by January. Farr *(1920)* says, "There is no relation, apparently, between the position of the bud on the twig and its state of development." He noted, however, that double and triple buds are not as far advanced as single buds, and that they generally are found near the proximal end of the twig. Roberts *(1922)* found that a similar relationship between the degree of development and the number of fruit buds borne at a single node held for the sour cherry. His studies also showed *(1917)* the "least total development of the blossom buds on the shortest growths, the greatest amount on the medium-length growths, and moderate development on the longest growths." On long terminal growths in the cherry, median buds were most developed, terminal buds least, and basal buds intermediate. The buds most advanced were also the least hardy.

While pollen of basal buds seemed to be at the same stage of development at bloom as pollen of median and terminal buds, the buds themselves were not always at the same stage. In some seasons, particularly early ones, terminal and median buds opened several days before basal buds. This was very noticeable in the early spring of 1927 (See Figure 2).

RELATIVE DEVELOPMENT OF POLLEN AND OVULE

While attention was given primarily to pollen development as an index of growth during the winter months, because of the fact that whole flower buds were sectioned it was possible to determine also from time to time the changes in the ovule. In the flower buds of Elberta which were collected on November 8, 1921, there was no growth on the carpel wall to indicate the first stages of ovule formation. At this time pollen from the same flowers was in the archesporial cell stage. The first outgrowths from the carpel wall were found on January third. By January 19 these occurred much more generally

and were much larger in some ovaries, but, as yet, the start of ovule development had not been made in some pistils. This variation in ovule growth is interesting in view of the stages reached in pollen development. Table 5 shows that pollen growth at this same date (January 19) had advanced considerably since the earlier collections.

In the collections made on February 20, ovule development had gone still farther, but as yet no growing points for the integuments had appeared. It was not until March 3 that these were found at a time when the pollen grains from the same flowers had been liberated from the tetrad wall (Table 5). By March 13, both integuments were present in some ovules, but they were not closed sufficiently to form the funiculus. Growth was relatively rapid between March 13 and 25. At the latter date the integuments were nearly closed in some instances, and there was a pronounced growth in the ovule, generally. Megaspore mother-cells were not found in the collections made on April 4, just as the flowers were opening. At this time the pollen grains were in a resting condition. The embryo sac, then, is not formed until after the first flowers open. It will be seen from the foregoing, therefore, that owing to the nature of the growth stages, pollen can be used as an index of winter growth to better advantage than the ovule because of the relatively later formation of the latter.

INFLUENCE OF CULTURE AND FERTILIZATION ON FRUIT-BUD HARDINESS

Relatively little attention has been given by investigators to the factors affecting the hardiness of the fruit bud, especially those that can be modified by the grower. The factors affecting wood hardiness have been studied much more extensively. Chandler *(1907)* as a result of his investigations believes that fruit-bud hardiness can be increased by inducing late growth and a tardiness in both entering and coming out of the rest period. As a result, the buds do not respond so quickly to spells of warm weather in January and February. Late growth can be brought about by pruning, fertilization, or cultivation. He found that thinning the previous crop tended to increase the hardiness of the flower buds. Garcia and Rigney *(1914)* found greater bud killing in the irrigated alfalfa sod part of a peach orchard than in the cultivated portion. On the other hand, Crane *(1924)* in peach fertilizer work in West Virginia found markedly greater killing of fruit buds on nitrated trees than on those not receiving it. Late applications of nitrate of soda killed a still higher percentage of fruit buds. The total number of live buds, however, on the nitrated trees

Fig. 2.—Terminal and median buds opening before basal ones.

was greater than on the checks because more buds were produced per shoot.

In view of these somewhat contradictory results further investigations were needed to determine the effect of culture on the extent of the rest period and also upon the internal differentiation and growth of the fruit bud. Kirby *(1918)* found that on spurs of the Jonathan and Grimes apples, fruit-bud initiation occurs first on trees in sod. He also found that fruit buds from trees in sod continued to be in a more advanced stage of development throughout the dormant season than did those from trees under cultivation.

It would seem, therefore, from the foregoing findings, that there is also a possibility of influencing the rate of fruit-bud development in the peach and thereby its hardiness by different cultural practices. Accordingly, in the spring and summer of 1924, some tests were made in the Variety Orchard on the Experiment Station Farm at Morgantown to determine the effect of applying nitrate of soda, at different times during the growing season, upon the hardiness of the fruit buds the following winter. The trees were eight years old and in good condition, although making a short terminal growth at the time the experiment was started. The pruning and culture were uniform on all trees under test. Again, 200 nodes were used as the basis for comparison, and were taken from one tree under each treatment. The winter of 1924-25 was so severe that fruit buds of only the hardiest varieties survived. It is during such conditions, however. that a treatment must be effective, if it is to have commercial value.

The data in Table 12, while not conclusive, are suggestive. The nitrated trees of Rochester and Salwey had noticeably fewer dead fruit buds than the checks. The earlier applications showed the same tendency in Belle, Bilmeyer, and Elberta, while with Champion there seemed to be no difference between the check and nitrated trees. During the winter of 1923-24, Carman and Waddell trees in sod had a noticeably greater percentage of their fruit buds killed than adjoining trees under cultivation. Comparison can be made between the fruit-bud killing in the varieties included in Table 3 with those of Table 12. The earlier applications of nitrate of soda appeared to induce slightly greater hardiness in the fruit buds.

Other seasons with less killing might show greater differences between the treatments than a season like 1924-25, the severity of which was near the limits of temperature endurance for fruit buds of the peach.

TABLE 12.—Effect of Fertilization with Nitrate of Soda on Fruit-Bud Killing (1924-1925) in the Variety Orchard at Morgantown.

Varieties	Times of Application	Amounts Applied in Pounds	Percentages of Buds Alive	Remarks
Apex	April 23	4	0	Tree in bloom at time of application.
Apex	July 15	4	less than 1	Occasional live bud on short growths.
Apex	Check		less than 1	Occasional live bud on short growths.
Belle	April 23	4	2	Occasional live bud on short growths.
Belle	July 15	4	1	Occasional live bud on short growths.
Belle	Check		2	Occasional live bud on short growths.
Champion	April 23	4	11	
Champion	July 15	4	7	
Champion	Check		12	
Late Crawford	April 23-July 15	3	0	
Late Crawford	April 23	4	0	
Late Crawford	Check		0	
Early Elberta	April 23	4	0	
Early Elberta	Sept. 10	4	0	
Early Elberta	Check		0	
Bilmeyer	April 23	4	2	Occasional live bud on short growths.
Bilmeyer	July 15	4	less than 1	Occasional live bud on short growths.
Bilmeyer	Check		less than 1	Occasional live bud on short growths.
Elberta	April 23	4	2	Occasional live bud on short growths.
Elberta	July 15	4	less than 1	Occasional live bud on short growths.
Elberta	Check		less than 1	Occasional live bud on short growths.
Reeves	Apr. 23, July 15 Sept. 10	3	0	
Reeves	Sept. 10	4	0	
Reeves	Check		0	
Rochester	April 23	4	22	Nitrated trees have noticeably more live buds.
Rochester	Sept. 10	4	29	
Rochester	Check		6	
Salwey	Apr. 23, July 15	3	9	
Salwey	Sept. 10	4	4	
Salwey	Check		less than 1	Few alive on short growths.

SUMMARY

The winters of West Virginia are characterized by periods of moderately high temperatures which cause considerable bud growth in the peach. When these high temperature periods are followed by sudden cold spells, especially toward late winter, conditions occur which favor bud killing.

The different peach varieties varied greatly in the hardiness of the fruit buds. Elberta and J. H. Hale were among the tenderest varieties, although not so much so as Reeves, the least hardy of all the varieties under observation. Greensboro was one of the hardiest varieties and with some of the others, like Carman and Mayflower, came through the winter of 1924-25 with some live buds.

Fruit-bud killing was not so extensive in the eastern part of the state as in the western part during the winters that this problem was studied. A crop loss may occur either east or west of the mountains from the killing of the fruit buds during the winter.

There was considerable variation in the way in which the different varieties may be affected by winter temperatures. The killing of the flower buds or the killing of the young pistils may eliminate a large proportion of the buds as far as setting is concerned. The killing of pistils, as in Late Crawford, was more extensive in 1921-22 than during any of the other years in which these varieties were studied.

Pollen development increased in rate early in December. Anther changes afforded a more sensitive index to growth than blooming tests, although the latter showed the approximate time of the break in the rest period.

These studies covering two seasons showed that the rest period ends earlier in Elberta than in Belle or Rochester. This condition favors a greater growth response in Elberta during the warmer periods of January and February than in Belle and Rochester. There was much variation in the stages of pollen development found at a given date and likewise a given stage was found for some time later.

There was considerable variation in the degree of development of the fruit buds on different parts of the tree by mid-winter, as measured by degree of pollen differentiation. Generally speaking, buds on the bases of the terminal twigs were latest in development, buds on the middle of the twigs next, and the terminal buds farthest advanced. The fruit buds borne on the short spurs or branches on the interior of the tree were on the average slightly ahead of the basal buds on the outside terminals. The indications are that the buds farthest advanced were the least hardy, although there is seemingly some evidence against this in Table 2.

Ovule development was noticeable at a much later date than that of pollen. The first stages of ovule formation were indicated by growing points on the carpel wall on January 3. Differentiation of integuments was noticed on March 3. Megaspore mother cells were not found in collections made on April 4, just as flowers were opening. The embryo sac, then, is not formed until after the first flowers open.

Nitrate applications were made in an attempt to influence bud hardiness. The results indicated a slight increase in hardiness on trees making but a short terminal growth.

LITERATURE CITED

BLAKE, M. A. and FARLEY, A. J.
1911. REPORT OF THE HORTICULTURIST. N. J. Agr. Exp. Sta. An. Rpt. 32:63-86.

BLAKE, M. A.
1916. REPORT OF THE DEPARTMENT OF HORTICULTURE. N. J. Agr. Exp. Sta. Rpt. 37:71-72.

BLAKE, M. A., and CONNORS, C. H.
1918. REPORT OF THE DEPARTMENT OF HORTICULTURE. N. J. Agr. Exp. Sta. Rpt. 39:41-64.

CHANDLER, W. H.
1907. THE WINTER KILLING OF PEACH BUDS AS INFLUENCED BY PREVIOUS TREATMENT. Mo. Agr. Exp. Sta. Bul. 74.

CHANDLER, W. H.
1908. HARDINESS OF PEACH BLOSSOMS AND YOUNG FRUIT AS INFLUENCED BY THE CARE OF THE ORCHARD. Mo. Agr. Exp. Sta. Circ. of Information 31.

CRANE, H. L.
1924. EXPERIMENTS IN FERTILIZING PEACH TREES. W. Va. Agr. Exp. Sta. Bul. 183.

DRINKARD, A. W.
1909-10. FRUIT-BUD FORMATION AND DEVELOPMENT. Ann. Rpt. Va. Agr. Exp. Sta. 159-205.

FARR, C. H.
1920. DORMANCY AND WINTER-KILLING OF PEACH BUDS. Trans. Iowa Hort. Soc. 55:99-116.

GARCIA, F. and RIGNEY, J. W.
1914. HARDINESS OF FRUIT BUDS AND FLOWERS TO FROST. New Mexico Agr. Exp. Sta. Bul. 89.

HODGSON, F. R.
1924. OBSERVATIONS ON THE REST PERIOD OF DECIDUOUS FRUIT TREES IN A MILD CLIMATE. Proc. Am. Soc. Hort. Sci. 151-155.

HOWARD, R. L.
1910. AN EXPERIMENTAL STUDY OF THE REST PERIOD IN PLANTS. Mo. Agr. Exp. Sta. Bul. 1.

JOHNSON, E. S.
1923. MOISTURE RELATIONS OF PEACH BUDS DURING WINTER AND SPRING. Md. Agr. Exp. Sta. Bul. 255.

KIRBY, R. S.
1918. A STUDY OF THE FORMATION AND DEVELOPMENT OF THE FLOWER BUDS OF JONATHAN AND GRIMES GOLDEN IN RELATION TO DIFFERENT TYPES OF SOIL MANAGEMENT. Proc. Iowa Acad. Sci. 25:265-287.

ODELL, I. H.
1924. HARDINESS OF PEACH VARIETIES. Trans. Ind. Hort. Soc. 167-168.

POJARKOVA, ANTONIA.
1924. WINTERRUKE, RESERVESTOFFE, UND KALTERESISTENZ BEI HOLZPFLANZEN. Ber. Deutsch. Bot. Ges. 42:10:420-429.

ROBERTS, R. H.
1917. WINTER INJURY TO CHERRY BLOSSOM BUDS. Proc. Am. Soc. Hort. Sci. 105.

ROBERTS, R. H.
1922. THE DEVELOPMENT AND WINTER INJURY OF CHERRY BLOSSOM BUDS. Wis. Agr. Exp. Sta. Res. Bul. 52.

STRAUSBAUGH, P. D.
1921. DORMANCY AND HARDINESS IN THE PLUM. Bot. Gaz. 71:337-357.

THAYER, P.
1916. WINTER KILLING OF PEACH BUDS. Ohio Agr. Exp. Sta. Mo. Bul. 1:311-312.

Bulletin 212 September, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

Morgantown

Adjusting Agricultural Production and Distribution in the Clarksburg Area to Meet Home Market Demands

An Important Agricultural Enterprise in the Clarksburg Area

By

W. W. ARMENTROUT

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------President of the University
HENRY G. KNIGHT, Ph. D.--------------Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr.--------------------Agricultural Editor
JOHN C. JOHNSTON------------------------------------Chief Clerk

AGRONOMY

R. J. Garber, Ph. D.
Agronomist

T. E. Odland, Ph. D.
Associate Agronomist

D. R. Dodd, M. S.
Assistant Agronomist

T. C. McIlvaine, Ph. D.*†
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, B. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

E. C. Stilwell, M. S.
Assistant Animal Husbandman

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

T. J. Cochrane, M. S.
Junior Chemist

Paul Daughenbaugh
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Junior Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, B. S.**
Assistant in Entomology

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D.
Home Economist

Nell Nesbitt, A. M.
Home Management Specialist

HORTICULTURE

Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

H. E. Knowlton, Ph. D.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, B. S. Agr.
Assistant in Horticulture

A. L. Tener, B. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Assistant Plant Pathologist

L. H. Leonian, Ph. D.
Assistant Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D.
Associate Soil Technologist

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Sociologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Adjusting Agricultural Production and Distribution in the Clarksburg Area to Meet Home Market Demands

This report is the second in a series of studies of consumption of farm products in the larger cities of West Virginia, and of production of such products in the agricultural sections adjacent to these cities. The first study of the series was of Charleston and its trade area, the report of which was published as West Virginia Agricultural Experiment Station Bulletin No. 188.

This bulletin, the second of the series, is the report of a study of food consumption in Clarksburg and its trade area and of farm production in Harrison County. The study was made in the summer of 1925. In its more important features, this study is comparable with the one of Charleston.

The Federal Bureau of Agricultural Economics cooperated in the first study, furnishing two members of its staff to assist in the work; this one was made entirely by staff members of the West Virginia Agricultural Experiment Station and Extension Division.

Purpose of the Study

Agriculture is continually facing periods of readjustment as population increases and industry grows. During the past ten years a need for readjustment in agriculture in some sections of the state has been felt keenly by farmers and agricultural leaders in West Virginia. The need for such adjustment has been intesified in Harrison and neighboring counties because of the general agricultural situation following the World War, because of the increase of population of cities in this part of West Virginia, because of the great increase in mileage of improved roads in this section, and because of the farmers' increasing need for money.

Economic adjustments will eventually work themselves out but, with an understanding of the forces at work as a basis of guiding adjustments, much loss of time, effort, and often wealth may be avoided. This study is an attempt to find out some of the economic facts about agriculture in the Clarksburg section and to interpret them with a view to bringing about readjustments with a minimum

loss to the agricultural and industrial interests of this section.

A Background for the Agricultural Situation in the Clarksburg Area

The early years of farming in Harrison County, as well as in the state and nation generally, formed a period of self-sufficing agriculture; that is, each farm produced what its farm family consumed, and consumed for the most part what it produced.

The farmer was not concerned with a market because he did not need to buy and had little to sell. His motive in farming was to produce food and clothing materials for his family. He was, therefore, guided in his production by the needs of his family, and to some extent by climatic and soil conditions. His welfare depended entirely upon the quantity of production on his own farm. He was not especially interested in articles for sale because he had only a limited need for money.

But along with industrial development has come a great need for money as a medium of exchange, and this has forced farming to become more or less of a commercial enterprise. To get the most money from farming means the economic production of those commodities which will sell for the most money. After due consideration of economic production the market demand is the chief guide as to what commodity and the quantity of it to produce.

Throughout the country agriculture is coming more and more to look to consumer demand as its guide for production, although it is surprising how little removed from the self-sufficing guide agriculture is in Harrison and similar industrial counties in West Virginia. There is, however, a very definite reason for this.

While agriculture in this section was in the beginning stages of transition from the self-sufficing to the commercial type, there came a great and rapid development of the coal, oil, and gas industries. Options amounting to from one to several dollars per acre were taken on much of the farm land in several counties. Royalties from oil and gas were received by many farmers, and the outright sale of coal lands gave others additional money. All in all, numbers of farmers found themselves with more money than they had ever had before. At that time, the need for money was, as compared with the present, not great. The farmer still produced a major portion of the commodities which his family de-

manded; taxes were not especially burdensome; there was little travel and hence little money outlay for transportation.

The money which the farmer received from mineral rights carried him through a period during which agriculture in other sections was becoming commercialized. During this period he came to utilize his land in a way most pleasing to himself without regard to the greatest money returns that were possible.

Within recent years, however, a different situation has arisen which calls for a readjustment in production. This situation has come from the increased needs of the farmers for money, accompanied by a decreasing return to them from mineral rights and a progressive exhaustion of money received from the sale of coal and timber. The farmers still produce much of their own food, but the demands for money have increased enormously because taxes have increased; modern transportation calls for additional money; and the farmers produce less and less of the things which modern life demands. With the advent of good roads much trade from the country and village store has gone to the city. In the village, produce could be exchanged for other desired commodities, but in the city, for the most part, it must be sold at one place and the commodities bought at another place. Barter has practically passed from the farmers' method of exchange. His need is for money and this brings him face to face with market demands. In order to get money for a commodity it must be something which people want, and the greater the desire for the commodity the more money the consumer will pay for it.

This study, then, was to ascertain the demands of the Clarksburg markets for certain commodities to use as a guide for production in Harrison and nearby counties. Resources at hand did not permit an exhaustive analysis of the economy of production of all the commodities considered in the market. In this report no pretense is made of giving the last word in the economy of production of any commodity considered.

As a general rule as population increases in a given locality, farming gradually changes to a more intensive type. But very often the cost of farm labor, due to high industrial wages in the territory, is out of proportion to the value of the land and agriculture remains more or less extensive. The high farm labor cost in the Clarksburg area is a very important factor in determining the type of farming

and should be reckoned with, even though other conditions are favorable for intensive farming.

The consuming population has been on the increase in Harrison County for a number of years with a resulting greater demand for food products.

POPULATION OF CLARKSBURG AND HARRISON COUNTY

The population of Clarksburg, according to the federal census was 27,869 in 1920 and in 1910 it was 9,210. The population increase in the ten year period was 18,659 but this is by no means all true increase. The corporate limits of the city were extended between 1910 and 1920 to take in two important suburbs. The increase in population is better shown by statistics for Harrison County in which Clarksburg is located. The population of the county was 27,690 in 1900; 48,381 in 1910; and 74,793 in 1920. Thus it may be seen that there has been a constant and quite rapid increase in population in the county during the past twenty years. Nearly half, or 41.2 per cent, of the population of the county was enumerated as urban in 1920. In reality the urban population made up a much larger percentage of the total than indicated, because the inhabitants of many mining villages were enumerated as rural, when, in fact, very few of them were in any way connected with agricultural production. From the standpoint of production and consumption of farm products they are in the same position as urban dwellers.

The desity of population for Harrison County in 1920 was 179.8 persons per square mile, while for the state as a whole it was 60.9 and for the United States it was 35.5. It is apparent then that in comparison with average conditions of population density, Harrison county has reached the point where intensive rather than extensive farming might well be practiced by many of its farmers. The same might well be said for adjacent territory.

If five persons constitute a family, there were approximately 15,000 families in the county. From census data it is estimated that the average farm in the United States will provide agricultural commodities sufficient for four families. There were 2,271 farms in Harrison County, and if they produced as much as the average farm for the United States, they would not feed more than about

half of the population of the county. The average farm in Harrison County, however, is not so large in either acreage or production as the average farm for the United States and as may be seen later in this report, the farms of the county actually supply much less than half of the food consumed in the area.

CLARKSBURG TRADE AREA

In the Charleston study, it was possible to define the trade territory more or less accurately; but for Clarksburg there is so much overlapping of trade territory with Parkersburg, Fairmont, Grafton, and Weston that it seemed unwise, in a study of this scope, to attempt to outline a trade territory. But no matter where the commodities are consumed, as long as they are distributed from Clarksburg, the quantity so distributed may be considered as the demand of this market.

The part of this study dealing with agricultural production was confined to Harrison County farms, but the data should be of value as a guide to production in neighboring counties, which normally use Clarksburg as a market.

AGRICULTURE IN HARRISON COUNTY

The following data for Harrison County have been adapted from the 1920 Census of the United States and are placed here for convenient reference.

Land area, 266,240 acres.
Land in farms, 232,981 acres.
Per cent of land area in farms, 87.5.
Per cent of farm land improved, 86.3.
Number of farms, 2,271.
Average acreage per farm, 102.06 acres.
Average acreage of improved land per farm, 88.5 acres.
Value of all crops, $2,292,904.
Value of livestock, $1,830,941.
Value of livestock products, $849,749.
Cereals, 14,450 acres.
Hay and forage, 26,214 acres.
Vegetables, 640 acres.
Miscellaneous crops, 5 acres.
Small fruits, 98 acres.
Number of fruit trees, bearing, 175,925; not bearing, 63,902.

A total of 41,407 acres in Harrison County was devoted to cultivated crops and hay. This is only 17.9 per cent of the land in farms in the county. It is thus apparent from census data as well as from observation that there is comparatively little of the land under cultivation. Much of the land is rugged, a considerable acreage, however, is gently rolling. It is difficult for one, unfamiliar with each individual farm, to estimate how much the crop land could be increased or whether it would be advisable to increase it at all. Each individual farmer must decide for himself what land he will crop and what crops he will grow. The purpose of this study is not to attempt to find data that would lead one to say that farmers generally should devote a certain acreage to a certain crop; but it is merely to present to the farmers the market demands.

The large area of bluegrass pasture is the basis of the livestock industry in the county. Fat cattle and lambs are sold off pasture in the summer and fall; grain fattening is not a common practice.

Dairy farming appears to be on the increase and there are a few farmers who devote their major efforts to truck and market gardening. Poultry and egg production have also become quite important sources of income.

RAILWAYS AND HIGHWAYS

Clarksburg is located on the main line of the Baltimore and Ohio Railroad. Branch lines of this railroad radiate in all directions. The West Virginia Short Line operates to Wheeling and points west; the West Virginia and Pittsburg branch to Richwood, Charleston, and points south; and the Monongahela Railroad branch gives direct connections to Pittsburgh and the north and west. The Monongahela West Penn Public Service Company also operates a passenger and package freight service over sixty-five miles of interurban lines, serving Fairmont, Weston, and intermediate points, with its principal terminal at Clarksburg. Farmers do not, however, make much use of freight facilities offered by this traction line in the marketing of their products.

The county has a fairly adequate system of highways. Improved roads extend in all directions from Clarksburg and traverse the better agricultural sections. No farmer has a great distance to travel before reaching a hard surfaced road. There are gaps and cross roads which need to be constructed or improved before good roads

are available to all farmers, but this county has made more progress than the average county of the state with its highways. The problem of getting to market is a comparatively easy one for most Harrison County farmers.

NEARNESS TO MARKET GIVES HARRISON COUNTY FARMERS AN ADVANTAGE

Transportation costs are a very considerable item in the price of food commodities. Distance from market determines transportation costs, and in general such costs increase with the distance over which commodities must be transported but not in proportion to this distance. Harrison County farmers and the farmers of nearby counties have a home market for practically all their produce. They necessarily have some transportation costs, but they are not nearly so high as those of competing sections farther away from Clarksburg.

The total freight bill for the year of this study (June 1, 1924 to May 31, 1925) on commodities included in this study was approximately $383,000. Practically all of this could be saved to the farmers if they could grow the products at home. It is necessary that the competitors haul the commodities to the railroad and load them on the cars and one may reasonably assume that it costs them somewhere near as much to do this as it would cost a Harrison County farmer to transport his product to Clarksburg.

This bill for transportation does not include money paid out for express and parcel-post, which amounts to a considerable sum. It was not possible to get express charges because express waybills are sent daily to Baltimore and there were no facilities available to collect this data. Neither was it possible to get charges on the parcels post receipts. If these could have been added the total transportation charges would have shown considerable increases.

Too often it is assumed that the whole of such a transportation bill could be saved to local farmers. Only a part of it can be saved economically for them, however, because there are certain seasons of the year when the added cost of producing each of these commodities would be far more than the saving in transportation, and quite often other sections of the country can grow and deliver a commodity in Clarksburg at less cost than the nearby farmer. So the nearness

to market is an advantage that may be offset by other disadvantages. Before producing any crop, the farmer should figure carefully whether it will increase his net returns from farming, rather than whether he can produce it as cheaply as it can be produced in some other section.

FREIGHT RECEIPTS OF SPECIFIED COMMODITIES AND THE PRODUCTION OF THESE COMMODITIES IN HARRISON COUNTY

The commodities included in this study were potatoes, cabbage, onions, lettuce, tomatoes, beans, corn, melons, miscellaneous vegetables, apples, eggs, meats, milk, hay, mixed feeds, flour, corn, and oats.

Each of the above commodities was being produced or may be produced in Harrison County or in other counties situated conveniently to the Clarksburg market. Market demand is judged by the quantity of the receipts, and while the quantity consumed will vary somewhat from year to year according to supply as reflected in price, yet the market demand, as long as the population does not decrease, will remain about the same. With an increasing population, however, there should be an increasing demand for food stuffs, so the demands will not likely fall below the quantity here shown.

The freight receipts are a summary from actual freight records for a twelve months period beginning June 1, 1924, and ending May 31, 1925. Both carlot and less-than-car-lot receipts were included. The bulk of the food commodities was transported by freight, but smaller quantities also came into Clarksburg by express and parcel-post. It was impossible to get actual records of receipts of the above mentioned commodities from Clarksburg express and post office therefore such receipts are not considered.

Estimates of the quantities of the various commodities sold from the farms of Harrison County are based on a canvass of 241 farms comprising 15 per cent of the farm land of the county. The record of the commodities shipped out of the county were taken from freight records and in the case of express, on estimates of the agents, of the various express offices of the county.

Potatoes

The records showed the receipt of 10,187,934 pounds or 169,799 bushels of potatoes by freight during the twelve months period included in the study. The potatoes were received by wholesalers, retailers, and some few, for the most part locally grown, were billed direct to the consumer. Of the total quantity referred to above, only 833, 348 pounds or 13,000 bushels were grown in West Virginia. Thus West Virginia supplied but 8 per cent of the potatoes which were received by freight in the Clarksburg market.

Potato Production Is Increasing in the Clarksburg Area.

From the records secured from 15 per cent of the farm acreage of Harrison County, it is estimated that 19,000 bushels of potatoes were sold from the farms of Harrison County. Not all of these were sold in Clarksburg, however. Many of them went to smaller towns and mining villages in the county. But if one supposes that all of these were sold on the Clarksburg market, even then West Virginia would have supplied only 17 per cent of the potatoes which reached the Clarksburg market. This estimate, however, does not take into account any potatoes which might have been received by freight in the smaller towns of the county but which did not pass through Clarksburg wholesale houses.

The chief thing of interest in this connection is that, at most,

less than one-fifth of the potatoes marketed in Clarksburg were grown in West Virginia. It would appear that there is an opportunity to increase production about five times before outside markets would need to be sought. In order to supply the market the year-round it would be necessary to provide storage but because of limited supply it is doubtful whether storage would be profitable for the individual grower. The bulk of West Virginia potatoes is marketed directly after they are harvested and thus all storage costs are eliminated. In a normal season they come on the market as the southern crop is about exhausted and before the western and northern crop arrive in large quantities. A monthly summary of potato receipts showing the state in which the shipment originated, the quantity in pounds and the freight charges will give a better idea of the extent to which production may be expanded.

TABLE 1.—Freight Receipts of Potatoes in Clarksburg; State from Which Shipped, Quantity, and Freight Charges by Months, June 1924 to May 1925, Inclusive.

State from Which Shipped	1924													
	June		July		August		September		October		November		December	
	Pounds	Freight Charges	Pounds	Freight Charges	Pounds	Freight Charges	Pounds	Freight Charges	Pounds	Freight Charges	Pounds	Freight Charges	Pounds	Freight Charges
South Carolina	387,930	$ 2,305												
Georgia	222,125	$ 1,467											32,000	$ 254
Virginia	36,000	$ 108	1,128,350	$ 5,268	145,260	$ 667	406,736	$ 2,071	63,000	$ 296	1,500	$ 4		
Michigan	30,000	$ 120					30,000	$ 120	69,000	$ 276				
Wisconsin	60,000	$ 297							69,900	$ 353				
Maryland	50,800	$ 169	71,910	$ 315	143,235	$ 592					31,624	$ 159		
West Virginia	20,604	$ 51	5,310	$ 17	180,200	$ 351	90,830	$ 274	425,090	$ 1,055	67,013	$ 186	1,000	$ 3
Kentucky			30,000	$ 111										
New Jersey							245,677	$ 881	96,036	$ 328				
Ohio							115				377	$ 1		
New York									36,000	$ 108	544,446	$ 1,642	220,240	$ 661
Minnesota									960,000	$ 5,409	144,000	$ 852		
Pennsylvania											41,795	$ 113		
Maine											41,525	$ 268	41,525	$ 376
Total	807,459	$ 4,517	1,235,570	$ 5,711	468,695	$ 1,610	773,358	$ 3,346	1,719,026	$ 7,825	872,280	$ 3,225	294,765	$ 1,294

TABLE 1.—Continued.

State From which Shipped	1925 January Pounds	January Freight Charges	February Pounds	February Freight Charges	March Pounds	March Freight Charges	April Pounds	April Freight Charges	May Pounds	May Freight Charges
South Carolina									70,300	$ 376
Georgia									31,820	$ 180
Michigan	159,200	$ 654	78,000	$ 326			78,000	$ 335		
Wisconsin			72,000	$ 371	182,840	$ 831	36,000	$ 94		
Maryland					206	$ 1			370	$ 1
West Virginia			222	$ 1	38,960	$ 117	4,119	$ 11		
Ohio			360	$ 1						
New York	404,386	$ 1,222	463,890	$ 1,338	591,710	$ 1,803	878,140	$ 2,675	617,208	$ 1,933
Minnesota			75,000	$ 419	108,000	$ 652	72,000	$ 370		
Cincinnati*					36,000	$ 79	150	$ 1		
Pittsburgh*					320	$ 1	44,500	$ 133		
Total	563,586	$ 1,876	662,472	$ 2,456	958,036	$ 3,484	1,112,989	$ 3,619	719,698	$ 2,490

*Rebilled from wholesale market.

TABLE 2.—Receipts of Potatoes In Clarksburg by States, Ranked According to Quantity, June 1924 to May 1925, Inclusive.

State	Pounds Received
New York	3,729,020
Virginia	1,780,846
Minnesota	1,359,000
West Virginia	833,348
South Carolina	458,230
Michigan	444,200
Wisconsin	420,740
New Jersey	341,713
Maryland	298,145
Georgia	285,945
Pennsylvania	86,615
Maine	83,050
Ohio	37,002
Kentucky	30,000

There were three other states which supplied more potatoes to this market than did West Virginia. The rank of the states will change from year to year according to the yield and price, but West Virginia probably has never ranked higher than at this time.

From Table 1 it may be seen that the bulk of the West Virginia potato crop went on the market in August, September, October, and November, with October and August being the leading months. There were a few bushels which went on the market in each of ten months while there were none in two months, January and May. The deliveries, except in the four months of heavy delivery, were for the most part in small quantities, usually in less-than-car-lots, and quite often they were billed direct to the consumer.

For the present the production program may well be based on the demands of the four months period over which West Virginia farmers market their potatoes. This will require no changing to earlier varieties or storage.

During August, September, October, and November, the West Virginia market period, 3,833,359 pounds of potatoes were received in Clarksburg. West Virginia supplied 763,133 pounds or approximately 20 per cent of these. This would indicate, taking production conditions as they are, that the production might be increased five fold before there would be an over-supply of the market. In any case local production must meet out-of-state competition during these months and this competition would not be much stronger if nearly

enough potatoes were produced locally to supply the market demands.

There might be some advantage in growing potatoes which would come on the market earlier but it would seem unwise to recommend storage as a general practice, when so many more potatoes than are now being grown can be marketed without storage.

A further analysis of each of the four months included above should be of value in planning the time to put the crop on the market.

During August 468,695 pounds of potatoes were received on the market, of which quantity West Virginia supplied 180,200 or 38 per cent. The production for local marketing during this month could not stand an increase of more than two and one-half fold. The competing states are Virginia and Maryland. This is getting near the end of Virginia's Eastern Shore product and it is claimed by some Clarksburg merchants that West Virginia potatoes are of higher quality at this time, than the Eastern Shore product.

The receipts for September totaled 773,358 pounds, of which West Virginia supplied 90,830 pounds or 11 per cent. There is an opportunity to increase production for local marketing nine fold during this month. The competing states were Virginia, New Jersey, Michigan, and Ohio.

For October the receipts were 1,719,026 pounds of which West Virginia supplied 425,090 pounds, or nearly 25 per cent. This indicates a chance for a four fold increase for the local market. October was the month of heaviest delivery of the West Virginia crop. The strongest competitor during this month was Minnesota, which supplied more than twice as many potatoes as came on the Clarksburg market from West Virginia. The average freight charge on the Minnesota potatoes was 56 cents per hundred pounds, while the average charge on the West Virginia product was 25 cents per hundred pounds. West Virginia has an advantage in location over its strongest competitor, Minnesota, amounting to 31 cents per hundred pounds.

For November the total receipts were 872,280 pounds. West Virginia supplied 7 per cent of this total. The West Virginia potatoes were marketed during the first part of the month and were really a part of the heavy delivery of October. The largest competitor during this month was New York, which suppiled more than

eight times as many potatoes as were marketed from West Virginia.

The average freight charge for all potatoes from West Virginia during this four months period of heavy local delivery including both those marketed in car-lots and those marketed in less-than-car-lots was 24 cents per hundred pounds. The freight charges for all other potatoes arriving on the Clarksburg market averaged 46 cents per hundred pounds. This gives an advantage of 22 cents per hundred pounds for West Virginia potatoes over the average for all competitors because of nearness to market.

The average freight charge for all potatoes received from West Virginia over the twelve months period studied was 24.5 cents per hundred pounds, while for all other potatoes it was 42 cents. On the basis then of yearly receipts West Virginia has an advantage of 17.5 cents per hundred pounds because of location.

From the standpoint of demand there is clearly an opportunity for increasing local potato production. It is then a question for each individual farmer to decide whether he can successfully compete in potato production. The following cost of production data are the most accurate available and may serve as a guide.

Studies of cost of production of potatoes in two sections of West Virginia were made in 1914 and 1920. The following quotation is taken from West Virginia Agricultural Experiment Station Bulletin 187, which is a report of these studies:

"In 1922 in Brooke County potatoes yielded 90.4 bushels per acre and were worth \$113.00. The cost of production was \$82.24 per acre leaving a net return of \$30.76 per acre or \$2.63 per man day. In Preston County in 1922 the yield of potatoes was 162.7 bushels valued at \$144.80. The cost of production was \$77.84, leaving a net return per acre of \$66.96 or \$5.78 per man day. Several sections of West Virginia are very well adapted to the production of potatoes. Lack of satisfactory method of marketing the crop has been the chief reason for not growing more potatoes."

In comparison with the foregoing costs of production of potatoes in West Virginia the following data on cost of potato production are adapted from Table 14 of Department Circular 340 of the United States Department of Agriculture in which in presented the cost of producing certain field crops in 1923.

Cost of Producing Potatoes in 1923.

Geographical Division	Yield per Acre (Bushels)	Net Cost per Acre	Net Cost per Bushel	Value per Acre	Value per Bushel
Northeastern	170	$ 105.50	$ 0.62	$ 172.34	$ 1.02
Eastern*	116	80.46	0.69	131.94	1.15
Southeastern	97	75.66	0.78	161.89	1.64
Central	101	52.48	0.52	80.12	.81
North Central†	116	51.34	0.44	52.76	.47
West So. Central	82	54.76	0.67	103.29	1.32
Western	149	68.83	0.46	97.07	.70

*Maryland, Virginia, West Virginia, North Carolina, Kentucky, Tennessee.
†Michigan, Wisconsin, Minnesota, North Dakota, South Dakota.

The yield in Preston County was higher and the cost of production lower per acre as shown in the quotation than the average for the Eastern states. These data are not quite comparable because the West Virginia study was made in 1922 and the study by the Department of Agriculture in 1923. The data are not necessarily applicable to Harrison and adjacent counties but they indicate that where there is a good yield and transportation charges are considered, this section of the state can compete very well with the North Central group of states.

Since the study referred to and reported in bulletin 187 of this Station was made, there has been a big improvement in the marketing of potatoes in West Virginia. The West Virginia Potato Growers Cooperative Association has been very successful in the operation of its "Potato Pool" for the past three years, and one of its greatest needs is a bigger volume of business. Farmers should now find no difficulty in marketing their potatoes at the going market price. It is true that before the advent of this association, individual growers could not market their product without undue trouble and often they were not able to find a market at all for their crops. Prices change from time to time. In Charts 1 to 4 and Tables 3 to 6 is presented a comparison of prices between the Clarksburg and Pittsburgh markets; West Virginia potatoes with out-of-state potatoes; and farm prices for the United States.*

Figure 1 and Table 3 show that the prices of potatoes averaged higher at Clarksburg and Fairmont than at Pittsburgh for the months of July, August, and September, 1925. In July and August, whole-

*The paragraphs on prices which are based on a price study during the summer of 1925 were contributed by Dr. Paul A. Eke, Assistant Farm Economist, West Virginia Experiment Station staff.

TABLE 3.—Comparison of Average Wholesale Prices Received for West Virginia Potatoes Sold Under "Mountain State Brand" in 150 Pound Bags with Average Wholesale Prices of Potatoes Sold as U. S. No. 1 in 150-Pound Bags at Pittsburgh, Wheeling, and Fairmont and Clarksburg, on Dates Specified from July 4, 1925, to September 26, 1925.*

Date	Price of "Mountain State Brand" Potatoes**	Price of U. S. No. 1 Potatoes at Pittsburgh	Price of U. S. No. 1 Potatoes at Wheeling	Price of U. S. No. 1 Potatoes at Fairmont and Clarksburg
July 4, 1925		$5.00		$4.32
July 11, 1925	$5.50	5.10		5.00
July 18, 1925	5.45	5.10		5.00
July 25, 1925	5.47	5.30	$4.20	5.25
Aug. 1, 1925	5.36	5.20	4.25	
Aug. 8, 1925	5.00	5.35	4.00	5.50
Aug. 15, 1925	3.75†	4.20	3.50	4.50
Aug. 22, 1925	4.07	3.95	3.50	3.60
Aug. 29, 1925	3.75	3.70	3.55	3.55
Sept. 5, 1925	3.50	3.30	3.30	3.45
Sept. 12, 1925	3.47	3.20	3.20	3.35
Sept 19, 1925	3.50	3.20	3.30	3.40
Sept. 26, 1925	3. 37	3.25	3.15	3.40

*Data are from records of wholesalers in the cities specified.
**This data for 43 carloads of "Mountain State Brand" (equivalent to U. S. No. 1) potatoes sold through the West Virginia Farm Bureau.
†One car only.

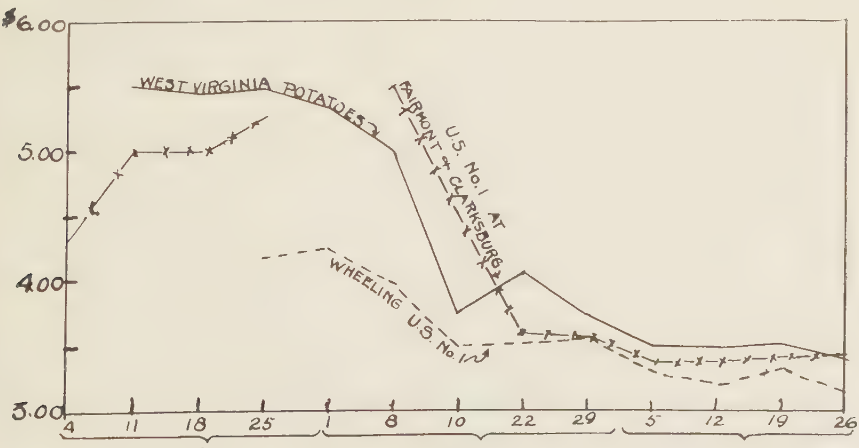


Fig. 1.—Comparison of Average Prices Received for Well Graded West Virginia Potatoes in West Virginia Markets and the Wholesale Prices of U. S. No. 1 on the Wheeling and Fairmont and Clarksburg Markets, Weekly, from July 4, 1925 to September 26, 1925. (Adapted from Data in Table 3)

sale prices at Pittsburgh were about 10 cents per 150-pound bag U. S. No. 1, above carlot prices at Clarksburg and Fairmont, but in September, carlot prices at Clarksburg and Fairmont ranged from 10 to 20 cents per 150-pound bag U. S. No. 1 above wholesale prices at Pittsburgh.

The average wholesale prices of potatoes at Pittsburgh included a large proportion of sales of less than carlot quantities. When this is taken into account it is certain that carlot prices were higher at Clarksburg and Fairmont with the exception of a few days, during the three months, July, August, and September. Fairmont, Clarksburg, and Pittsburgh, were better markets than Wheeling for the summer.

The second column shows the average wholesale prices received for 43 carloads of West Virginia potatoes which were graded U. S. No. 1 and put up in 150-pound bags under "Mountain State Brand." Most of these potatoes were sold in West Virginia cities. A few cars were sold in Pittsburgh. It will be noted that for all weeks, except two, higher prices were received for them than were paid for out-of-state commercial potatoes of the same grade at Pittsburgh, Wheeling, and Fairmont and Clarksburg. Premiums were realized on practically all sales made in West Virginia, but the cars which were sold in Pittsburgh, were sold at the same price as out-of-state, U. S. No. 1 potatoes. One must conclude therefore, that the people of West Virginia are willing to pay a premium for potatoes grown in this state even though this is not true on markets outside of the state.

Figure 2 and Table 4 show that grocers at Clarksburg were willing to pay premiums of as high as $1.00 per 150-pound bag for potatoes grown in West Virginia. These potatoes were put upon the market by a cooperative marketing association, which has enforced uniform grading upon its members. This table points out the reward which consumers are willing to offer for standardized, well graded West Virginia potatoes.

Figure 3 and Table 5 show that the average yearly prices per bushel of potatoes paid to growers in West Virginia from 1909 to 1924 have been, with very few exceptions, higher than prices prevailing in three northern winter crop producing states. The same is true when West Virginia is compared with Virginia. Therefore, potato producers in West Virginia have been able to obtain a premium over the prices received in these other states.

The premium paid for potatoes in West Virginia over prices paid in Minnesota, and Michigan, have continually increased since the close of the war in 1918. This tendency has been true to a less extent when prices in West Virginia are compared with prices in Maine and Virginia. The reason must undoubtedly be sought in the increased freight charges since the close of the war. Potato growing has become less profitable at long distances from the market and in areas of surplus production, and more profitable near the centers of population and in areas of deficient production. We can conclude therefore that potato growing in West Virginia will continue to obtain the present premium as long as freight charges remain at the present high level, and as long as West Virginia does not produce more than enough to supply the home demand.

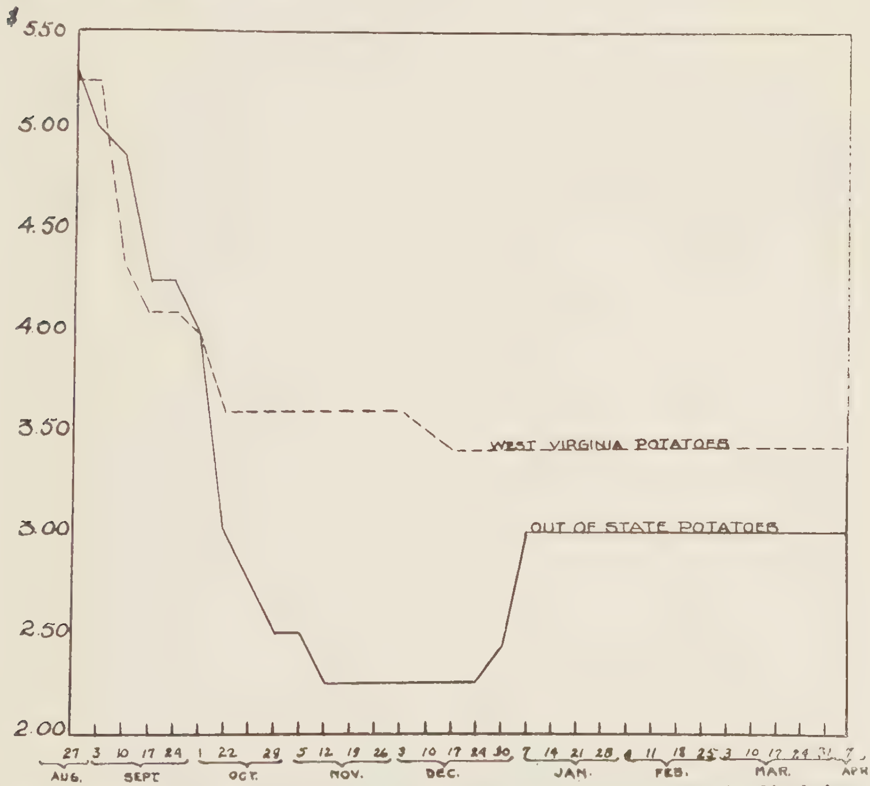


Fig. 2.—Jobber Prices Per 150-pound Bag of U. S. No. 1 Potatoes in Clarksburg Compared with Jobber Prices of Potatoes Grading U. S. No. 1 Bought from West Virginia Potato Growers Cooperative Association on the Same Dates and Markets, Weekly Average August 27, 1923 to April 7, 1924. (Adapted from Data in Table 4).

TABLE 4.—Jobber Prices per 150-pound Bag of U. S. No. 1. Potatoes in Clarksburg, Compared to Jobber Prices of Potatoes Grading U. S. No. 1. Bought From West Virginia Potato Growers Cooperative Association, on the Same Dates and Market, May 21, 1923 to April 14, 1924, Inclusive.*

Jobber Prices at Clarksburg per 150-pound Bag, U. S. No. 1 Grade

Date	Out-of-State Potatoes	Co-op. Association Potatoes	Date	Out-of-State Potatoes	Co-op. Association Potatoes
1923			Dec. 10	2.25	3.60
May 21	$2.85	$3.60	Dec. 24	2.25	3.00
May 28	2.60	3.60	Dec. 30	2.25	3.40
June 4	2.40	3.60	1924		
June 11	2.35	3.40	Jan. 7	2.40	3.40
June 18	2.35	3.35	Jan. 14	3.00	3.40
June 25	2.35	3.25	Jan. 21	3.00	3.40
Aug. 27	5.35	5.25	Jan. 28	3.00	3.40
Sept. 4	5.00	5.25	Feb. 4	3.00	3.40
Sept. 10	4.85	4.35	Feb. 11	3.00	3.40
Sept. 17	4.25	4.10	Feb. 18	3.00	3.40
Sept. 24	4.25	4.10	Feb. 25	3.00	3.40
Oct. 1	3.90	4.00	Mar. 3	3.00	3.40
Oct. 22	3.00	3.60	Mar. 10	3.00	3.40
Oct. 29	2.75	3.60	Mar. 17	3.00	3.40
Nov. 5	2.50	3.60	Mar. 24	3.00	3.40
Nov. 12	2.50	3.60	Mar. 31	3.00	3.40
Nov. 19	2.25	3.60	Apr. 7	3.00	3.40
Nov. 26	2.25	3.60	Apr. 14	3.00	3.40
Dec. 3	2.25	3.60			

*Data are from West Virginia Potato Growers' Cooperative Association records, and records of Clarksburg jobbers.

Since a bushel of potatoes can be sold in West Virginia at an average of 98 cents, when potato growers obtain from 27 to 35 cents per bushel in Minnesota, and Michigan, it is certain that potatoes can be grown at a profit in West Virginia for the winter as well as the summer market. It does not seem possible that potatoes in West Virginia can average much less than $1.00 per bushel even on years of great production for the country as a whole.

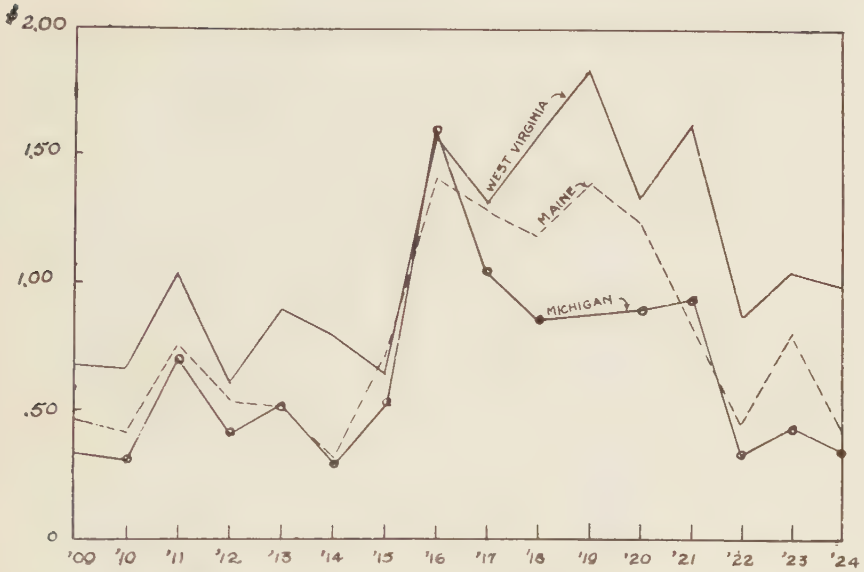


Fig. 3 —Farm Prices of Potatoes in Maine and Michigan Contrasted with Farm Prices in West Virginia, Yearly Average 1909 to 1924, Inclusive. (Adapted from Data in Table 5).

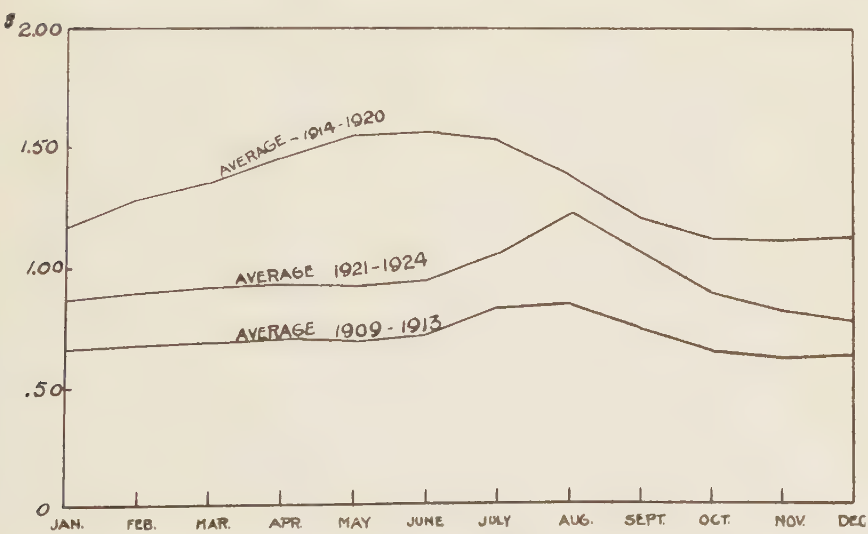


Fig. 4.—Average Farm Price per Bushel of Potatoes on 15th of Each Month, 1909 to 1924, Inclusive, Divided Into Three Periods. (Adapted from Data In Table 6).

TABLE 5.—Farm Prices of Potatoes per Bushel in Certain States Compared with Farm Prices in West Virginia, 1909 to 1924, Inclusive.*

State	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
W. Va.	.68	.67	1.04	.62	.90	.81	.65	1.58	1.32	1.60	1.75	1.35	1.63	.87	1.05	.98
Maine	.47	.42	.77	.55	.53	.33	.70	1.42	1.30	1.20	1.40	1.25	.85	.45	.70	.45
W. Va. Premium	.21	.25	.27	.07	.37	.48	—.05	.16	.02	.40	.35	.10	.78	.42	.35	.55
W. Va.	.68	.67	1.04	.62	.90	.81	.65	1.58	1.32	1.60	1.75	1.35	1.63	.87	1.05	.98
Michigan	.35	.31	.71	.41	.53	.30	.56	1.60	1.05	.89	1.35	.92	.95	.34	.44	.35
W. Va. Premium	.33	.36	.33	.21	.37	.51	.09	—.02	.27	.71	.40	.43	.68	.53	.61	.53
W. Va.	.68	.67	1.04	.62	.90	.81	.65	1.58	1.32	1.60	1.75	1.35	1.63	.87	1.05	.98
Minn.	.35	.64	.58	.28	.52	.32	.39	1.30	.91	.75	1.53	.80	.90	.35	.39	.27
W. Va. Premium	.33	.03	.46	.34	.38	.49	.26	.28	.41	.85	.22	.55	.75	.52	.66	.71
W. Va.	.68	.67	1.04	.62	.90	.81	.65	1.58	1.32	1.60	1.75	1.35	1.63	.87	1.05	.98
Virginia	.70	.58	.96	.65	.80	.77	.61	1.37	1.25	1.20	1.57	.98	1.10	.60	1.00	.81
W. Va. Premium	—.02	.09	.08	—.03	.10	.04	.04	.21	.07	.40	.18	.40	.53	.27	.05	.17

*Data from Year Books of United States Department of Agriculture.

TABLE 6.—Farm Price of Potatoes per Bushel, 15th of Each Month, for United States, 1909 to 1924 Inclusive.*

Year Beginning July	Price per Bushel in Cents by Months												
	July 15	Aug. 15	Sept. 15	Oct. 15	Nov. 15	Dec. 15	Jan. 15	Feb. 15	Mar. 15	Apr. 15	May 15	June 15	Weighted Average
1909	88.0	78.3	67.9	61.0	56.0	55.0	56.1	55.4	51.0	42.9	37.9	38.8	57.9
1910	52.5	68.9	70.4	61.8	55.7	54.9	54.6	55.2	55.4	59.0	62.9	79.8	61.3
1911	116.2	124.8	101.0	82.3	78.1	82.2	89.4	98.2	109.6	122.2	123.5	111.6	99.6
1912	95.0	75.8	58.0	48.3	48.0	50.6	51.8	52.6	51.2	49.2	51.7	52.5	55.6
1913	59.5	72.2	74.6	71.8	69.2	68.6	69.0	70.2	70.4	70.7	71.4	76.4	70.6
Av. 1909-13	82.2	84.0	74.4	65.0	61.4	62.3	64.2	66.3	67.5	68.8	69.5	71.8	69.0
1914	84.3	81.0	69.8	58.8	50.8	49.2	50.0	50.4	49.1	49.2	50.6	51.4	58.0
1915	54.2	53.4	49.6	54.8	61.2	66.2	79.3	91.2	96.0	96.2	96.8	100.6	70.8
1916	98.8	102.4	110.6	123.8	140.9	146.7	159.8	206.6	237.7	257.2	276.8	261.0	166.3
1917	209.4	155.0	130.6	125.0	125.3	121.9	122.0	121.6	106.4	86.4	77.8	85.2	122.5
1918	118.2	145.2	146.2	135.4	123.2	117.7	115.2	111.9	107.4	112.2	120.2	124.9	125.6
1919	160.6	190.2	175.8	158.5	156.2	169.0	198.1	230.6	269.6	344.6	407.4	403.6	223.8
1920	344.4	243.9	159.8	126.6	116.4	110.0	100.6	89.8	80.9	72.9	67.6	68.5	131.5
Av. 1914-20	152.8	138.7	120.3	111.8	110.6	111.5	117.9	128.9	135.3	145.5	156.7	156.5	128.4
1921	103.4	152.8	153.1	130.6	116.8	109.4	112.0	116.6	115.7	109.0	104.2	103.7	121.3
1922	109.0	101.4	78.8	66.2	60.5	58.8	62.0	64.2	68.6	77.4	79.0	79.8	73.9
1923	102.9	120.8	109.6	91.4	82.5	81.5	86.4	88.1	87.8	91.1	91.3	100.7	94.2
1924	109.0	111.3	81.0	68.8	63.5	64.1	------	------	------	------	------	------	--------------
Av. 1921-24	106.1	121.6	105.6	89.2	80.8	78.5	86.8	89.6	90.7	92.5	91.5	94.7	96.5

*Data from Year Book, United States Department of Agriculture, 1924.

The following conclusions may be drawn from Figure 4 and Table 6.

Over a period of years the average price of potatoes for the United States as a whole is the highest in July and August.

Only in years of large production are prices often lower during the late winter and spring months than during the fall months.

In case good yields may be obtained in West Virginia for early digging in July and August, it is advisable to grow potatoes, for the July and August markets. Table 6 shows further that profitable, although somewhat lower, prices may be obtained in West Virginia during the fall and winter.

Cabbage

The freight receipts of cabbage in Clarksburg totaled 1,390,862 pounds for the twelve months period included in the study. Of this total, West Virginia supplied 2,382 pounds, which went on the market during the month of October. A wholesaler received a shipment of 1,490 pounds of this West Virginia cabbage, and the remainder was made up of small shipments billed direct to consumers. In Table 7 the receipts of cabbage by months are presented.

TABLE 7.—Total Freight Receipts of Cabbage in Clarksburg by Months, and Receipts from West Virginia, June 1924 to May 1925, Inclusive.

Months	Total Number of Pounds Received	Pounds Received From West Virginia
1924		
June	166,555	none
July	161,700	none
August	30,500	none
September	24,490	none
October	263,272	2,382
November	157,100	none
December	52,800	none
1925		
January	102,340	none
February	108,765	none
March	149,105	none
April	102,075	none
May	72,160	none
Total	1,390,862	2,382

From Table 7 it may be seen that there is a market for cabbage every month in the year. The month of August shows the smallest receipts, and it is during this month that considerable local cabbage

is marketed direct to consumers. In June and July receipts were greater, and in October when late cabbage was ready for market, there were the largest receipts of the year.

The following competing states supplied cabbage on the Clarksburg market, during the months specified:

June: Mississippi, Alabama, Virginia, and Tennessee.
July: Ohio and Virginia.
August: Ohio.
September: Wisconsin.
October: West Virginia and New York.

From the survey of the Harrison County farms it is estimated that 283,297 pounds of cabbage were sold from Harrison County farms between June 1924 and May 1925. This is an indication that the crop can be produced in the county. The demands of the market fully warrant an increase in production, if farmers find that it can be produced economically.

Onions

There were 1,325,993 pounds of onions placed on the Clarksburg market by freight shipments, none of which were brought in from West Virginia. A few, however, were grown and marketed locally. Most of these grown locally were marketed in bunches as green onions. The quantity of such is very small and the production is limited to a few farmers who are specializing in market gardening. It would be a doubtful undertaking to attempt to grow large quantities of onions in competition with some of the more favorable sections, such as on the muck soils of Ohio and in sections of New York. However, where there are small patches of fertile land on which onions may be grown successfully, this crop would undoubtedly be profitable, for there is no lack of market for them in Clarksburg.

Onions came from other states as follows, during the months specified:

June: California.
July: Kentucky, New York, Virginia, and Washington.
August: New York and Ohio.
September: New York, Ohio, and Indiana.
October: New York and Ohio.

TABLE 8.—Freight Receipts of Onions in Clarksburg, by Months, June 1924 to May 1925, Inclusive.

Months 1924	Number of Pounds Received	Months 1925	Number of Pounds Received
June	30,240	January	75,000
July	181,185	February	192,425
August	71,550	March	none
September	174,447	April	63,336
October	231,425	May	123,760
November	73,700		
December	108,925		
		Total	1,325,993

Tomatoes

In Table 9 is presented the freight receitps of tomatoes in Clarksburg.

TABLE 9.—Freight Receipts of Tomatoes in Clarksburg, by Months, June 1924 to May 1925, Inclusive.

Months	Number of Pounds Received
1924	
June	150,320
July	146,316
August	24,245
1925	
May	71,400
Total	392,281

From Table 9 it may be seen that Clarksburg receives 392,281 pounds of tomatoes by freight. Local tomatoes came on the market in the latter part of July and August, and supplied the market until early fall almost entirely.

The local market is reasonably well supplied by local production of tomatoes after the season is well under way. There are often gluts on the market in the midst of the local harvest season, when town gardens come into bearing and the surplus from farm gardens comes on the market. There is not much opportunity for increasing the production of tomatoes with profit during the period when the local product normally comes onto the Clarksburg market. If income from tomatoes is to be increased it seems that changes would have to take place along lines of earlier ripening, better quality, more

Greenhouse in the Clarksburg Area Where Vegetables Are Grown for Out-of-Season Supply.

economical production, and better marketing, including grading and packing. There is no indication that the section of country around Clarksburg is adapted to the commercial growing of tomatoes beyond a supply for the local markets, and it appears as though this local demand is very well supplied during the normal season of local production. There is a splendid opportunity for the production of tomatoes under glass during winter, since fuel, one of the large items of expense, is comparatively cheap.

Tomatoes were received in Clarksburg from Florida, Mississippi, Tennessee, Maryland, and Ohio.

Strawberries

The freight receipts of strawberries on the Clarksburg market are presented in Table 10. There were no receipts by freight other than during the months shown in the table.

TABLE 10.—Freight Receipts of Strawberries in Clarksburg by Months, June 1924 to May 1925, Inclusive.

Months and Years	Number of Crates Received
June, 1924	2,193
May, 1925	1,040
Total	3,233

From Table 10 it may be noted that 3,233 crates of strawberries were delivered on the Clarksburg market by freight. These berries came from Kentucky and Tennessee. It is likely that many additional strawberries came onto the market by express.

Miscellaneous Vegetables

A large part of the vegetables which came into Clarksburg were shipped in cars billed as "mixed vegetables." It was, therefore, impossible to ascertain the quantity of each of the various kinds of vegetables received. A great part of these vegetables came from the Pittsburgh and Cincinnati markets. In Table 11, the quantity of vegetables received in "mixed cars" is presented.

TABLE 11.—Freight Receipts of Vegetables in Mixed Cars, in Clarksburg, by Months, June 1924 to May 1925, Inclusive.

Months 1924	Number of Pounds Received	Months 1925	Number of Pounds Received
June	90,729	January	114,050
July	110,340	February	117,875
August	1,270	March	235,830
September	116,540	April	338,465
October	120,885	May	310,999
November	195,901		
December	104,385		
		Total	1,857,269

From Table 11 it may be observed that during only one month in the year, August, did local production come anyways nearly supplying the demand for vegetables. Even then small shipments came in from the Pittsburgh market. During August local production is at its height and not infrequently is there a glut on the market. The glut is caused for the most part by the surplus vegetables produced by farmers who do not make a business of vegetable growing, and who made no plans as to the time when the product should come onto the market. The product is a surplus which they have from their home gardens and truck patches. At about this time the gardens of the suburban dwellers and some miners come into use.

Lettuce Is in Great Demand the Year Around. With Cheap Fuel Available There Appears to be Excellent Opportunities for Growing Lettuce Under Glass to Supply Local Markets.

There is often a glut in the market for green beans, tomatoes, and corn at this season of the year. At times there is a glut in the lettuce market, but this is due to the fact that there is not nearly enough produced locally to supply the demand and the wholesaler must order by the car load to supply his customers. At times this leaves the local producer without a very good market. This situation can be remedied only by increasing local production sufficiently to make it unnecessary for the wholesaler to buy from outside for a short period. This might be helped by all the lettuce growers offering their product on the market at the same time and notifying wholesalers in advance of the time when it is ready.

Aside from August the lowest receipts for the year were in June when 90, 729 pounds of vegetables were received. There is a heavy demand for vegetables all through the winter months. There are a few men around Clarksburg who have seen the opportunity in growing vegetables. While market conditions have not always been satisfactory it has been chiefly due to poorly planned production and a "cut throat" system of marketing. There seems an

especially good opportunity for many farmers whose farms are adapted to such to produce vegetable and truck crops for the Clarksburg market.

There Is a Large Demand for Celery, Which Has Been Grown with Success on a Small Scale in the Clarksburg Area.

Too often when vegetable growing is mentioned, the farmer thinks only of beans, tomatoes, potatoes, and corn. But there are many vegetables which are just as much in demand and bring higher returns. There is a woeful shortage of winter salads, such as spinach and kale, on the Clarksburg market. There is always a good market for asparagus, celery, peppers, egg plant, cucumbers, and the root crops. Vegetable growers would do well to turn their attention to the production of some of the above mentioned crops.

Apples

Table 12 shows the receipts of apples by freight on the Clarksburg market for the period studied.

TABLE 12.—Freight Receipts of Apples in Clarksburg by Months, June 1924 to May 1925, Inclusive.

Months 1924	Number of Pounds Received	Months 1925	Number of Pounds Received
June	163,208	January	436,970
July	22,540	February	267,000
August	53,445	March	168,560
September	150,537	April	250,040
October	310,013	May	60,030
November	631,837		
December	246,308		
		Total	2,760,488

From Table 12 it may be seen that the total receipts of apples by freight were 2, 760, 488 pounds or 46,000 bushels. The low months in receipts were May, July, and August. The estimate from the farm survey indicates that 29,000 bushels of apples were sold from Harrison County farms. There are a few commercial orchards in the county and a great many small farm orchards. It is doubtful if there is room for profitable expansion in the orchard industry of the county, but a few good commercial orchardists should find a good demand for their crop.

Some apples are shipped to Clarksburg from the orcharding section of the Eastern Panhandle, but the large majority of them come from other states. Excessive freight rates make it difficult to market West Virginia apples in the state.

Packing House Products

Table 13 shows the quantity of packing house products received on the Clarksburg market during the period studied.

The receipts of meats and packing house products as shown in Table 13, totalled 11,164,598 pounds. It was impossible to separate this total into the various meats and packing house products from information given on freight records, and records of the dealers were also inadequate for such information. This total includes fresh and cured meats, lard, sausage, etc. The bulk of the packing house products came from Chicago and Minneapolis. There is some local slaughtering but this takes care of a very small part of the trade.

TABLE 13.—Freight Receipts in pounds of Meat and Packing House Products by Months, June 1924 to May 1925, Inclusive.

Months 1924	Number of Pounds Received	Months 1925	Number of Pounds Received
June	914,053	January	1,026,245
July	1,132,846	February	1,074,335
August	1,034,236	March	746,135
September	938,344	April	909,268
October	837,831	May	881,328
November	911,755		
December	758,222		
		Total	11,164,598

Cattle and lambs are the only farm products grown in the county which are shipped out of the state in any quantity. There are not enough hogs produced to supply the local demand. Records from the various shipping points of the county show that there were 417 car loads of livestock shipped from the county during the twelve months period included in the study. This includes cattle, lambs and a very few hogs.

TABLE 14.—Livestock Shipped Out of Harrison County in 1924.

Shipping Point	Number of Cars Shipped
Bridgeport	140
Wolf Summit	10
Wilsonburg	12
Lost Creek	125
Salem	109
Dola	21
Total	417

It seems like a big loss in transportation to ship out the local cattle and ship in dressed meat from Chicago, and Minneapolis, but it appears as though the large packing houses, even at a great distance from consumer markets are able to save enough in overhead costs and in by-product utilization so that small local packing plants cannot compete successfully with them. A local packing plant, if it slaughtered only the small quantity produced locally, would most likely meet with poor financial success.

The people of West Virginia are eating very little of the good

quality meat that is being produced on their bluegrass pastures, because the most of it goes onto the eastern markets, while western meat, a great part of it dairy stock, comes onto the local market.

Harrison County is naturally a livestock county, but if land values continue to rise in proportion to wages for farm labor more farmers will find it profitable to turn their attention to dairying and other intensive types of farming. There is much land in the county, however, which can be utilized to best advantage only as pasture for some kind of livestock, whether it be beef cattle, dairy cattle, or sheep.

Poultry and Eggs

The poultry and egg situation in the Clarksburg market is one that is very difficult to analyze. Some poultry and eggs are received in the cars billed as packing house products. Others come in by express and parcel-post. The available records indicate that Clarksburg received about 46,000 pounds of poultry from other counties in West Virginia, and about 15,000 pounds from other states. On the other hand, records from shipping points in the county show that approximately 25,000 pounds of poultry were shipped from the county going mostly to eastern markets. Records from the farm survey show that approximately 143,000 pounds of poultry were sold from the county, the major part of this going to the Clarksburg market. In so far as the poultry situation is concerned it appears that there is about a balance between production and consumption when Harrison and nearby counties are considered. A large increase in the poultry industry will mean looking for markets outside of the county.

TABLE 15.—Poultry Shipped From Harrison County, 1924.

Shipping Point	Number of Pounds Shipped
Bridgeport	2,450
Lost Creek	2,500
Salem	16,800
Dola	1,680
Total	23,430

The estimate from the farm records shows the sale of about 650,000 dozens of eggs from the county. Records from the shipping

points in the county show the shipment of 8,700 dozens of eggs, which is probably less than the parcel-post and express receipts from outside the state. This indicates that there is not a surplus production of eggs in the county.

TABLE 16.—Eggs Shipped from Harrison County, 1924.

Shipping Point	Number of Dozens Shipped
Bridgeport	1,500
Lost Creek	3,600
Salem	2,160
Dola	1,440
Total	8,700

Dairying

The dairy industry has reached the point in Harrison County where it just about supplies the demand of the city for fluid milk. During the twelve months period included in the study, Harrison County supplied 95 per cent of the fluid milk consumed in the city. The producers distributed 4,000,000 pounds and the milk distributing plant 2,120,000 pounds, making a total of 6,120,000 pounds. This does not include the milk from a few one-and two-cow dairies in the city, but these would not materially increase the total. Of the total number of pounds consumed only 156,600 pounds or 2.5 per cent came from outside of West Virginia. On the basis of the above data the daily per capita consumption of fluid milk in Clarksburg was about .6 of a pint. Approximately 4,500 gallons of 20 per cent cream were brought into the city from outside the state for the manufacture of ice cream in the drug stores and in one small ice cream plant. The largest ice cream plant in the city failed to supply records of the quantity of cream which it used. All of it, however, came from outside of Harrison County, and the greater part of it from outside of the state.

Milk retailed in the city at from 14 to 18 cents per quart. There was not a uniform price on the milk routes operated by the dairymen. The milk distributing plant in the city paid for milk on the butter fat basis. For January, February, March and up to April 26, 1924, the price was $3.95 per hundred pounds for 4 per cent milk and 5 cents additional for each .1 per cent butter fat above this test.

For the remainder of April, May, and June the price was $2.80; for July, August, September, and October, $3.00; and for November and December $4.00 for 4 per cent milk plus 5 cents for each additional .1 per cent butter fat.

A total of 2,308,000 pounds of condensed milk and milk powder was received by freight on the Clarksburg market during the period studied.

For an expansion of the dairy industry in Harrison County there are three lines of action: First, total consumption of milk may be increased; second, milk may be produced for manufacturing purposes, that is, ice cream, butter, and cheese; or, third, the consumption of condensed milk may be replaced by fluid milk.

Consumption may possibly be increased by an advertising campaign and the present price maintained, but a decrease in price might increase consumption much faster.

The present high price for fluid milk is due to the fact that so much of it is produced in roadside dairies where all feed is bought. Dairy farmers growing a part of their feed could probably produce milk at a cost which would justify them in selling it at manufacturing prices, but markets for such would need to be developed. At any rate, the fluid milk market in Harrison County is fast nearing the point of saturation.

The major portion of the milk from outside the state came onto the Clarksburg market in January, February, March, and April. An increase in local production of from 10 to 15 per cent could be absorbed during these four months.

Concentrated Feeds and Hay

In Table 17 are presented the receipts of hay and concentrated feed on the Clarksburg market. Corn, oats, and mixed feeds; that is, poultry and dairy feeds, were included under this classification.

From Table 17 it may be seen that more than 43,000,000 pounds of concentrates and 10,000,000 pounds of hay were received during the twelve months period, while the estimate from the farm surveys shows the sale of 621,000 pounds of hay and 50,000 pounds of corn. An increase in the acreage of corn and oats would probably not be advisable. Much of the land is too steep for economical cultivation and the land that lies well enough for cropping may better be utilized

in other crops. There might well be a reduction in the corn acreage, except for ensilage. The freight charges on grain are small in comparison with its value, and other sections of the country can produce grain crops to a much better advantage than Harrison County.

TABLE 17.—Freight Receipts of Hay, Grain, and Grain Products at Clarksburg, by months, June 1924 to May 1925, Inclusive.

Months	Pounds of Hay Received	Pounds of Grain and Grain Products Received
1924		
June	616,914	1,792,877
July	363,035	2,702,701
August	209,100	4,135,205
September	767,041	4,219,881
October	1,171,302	3,910,123
November	1,320,616	4,100,652
December	1,177,230	4,013,563
1925		
January	987,544	3,142,318
February	1,229,891	4,591,772
March	1,049,285	4,110,076
April	788,187	3,749,635
May	342,893	2,726,922
Total	10,023,038	43,195,725

There is a different situation when it comes to hay. The freight charges are high in comparison with the unit value of hay. It is common for thickly populated sections to turn to intensive farming and hay production as the population increases and land increases in value. The chief reason for this is that the carrying charges increase so greatly the value of a bulky feed such as hay. Readjustments should include plans for capacity production of hay and ensilage.

Marketing

There are three wholesalers in Clarksburg who handle the major portion of the produce and vegetables for the city. There are numerous retail groceries and meat markets in the city. In addition to these distributors there are a number of huksters and farmers who peddle farm products from door to door. The number of such was not ascertained, but there was a considerable number of them operating, especially during the local producing season. There are no

regulations governing the marketing activities of such hucksters and farmers.

There is dissatisfaction on the part of both the farmers and the distributors over the present marketing situation. The farmers claim that the merchants do not give them a fair price when they offer their produce to them. The merchants accuse the farmers of unfair competition in their peddling and of later offering them the poor quality product which they have failed to sell on their peddling routes. There are two sides to the controversy, and it is one that both merchants and farmers must understand before it can be settled to the mutual advantage of all parties concerned.

There are a number of farmers who are specializing in growing vegetables and truck for sale in Clarksburg. There are a number of others who have a surplus of such products as beans, tomatoes, and eggs, which they market in the midst of the season. No one of these farmers produces any considerable quantity of the products, in fact, as has been shown earlier in this report, they do not altogether produce nearly enough to supply the market. Furthermore, there is no uniformity of production from one season to the next. Some few of the farmers have regular customers whom they attempt to supply with certain commodities, and make several trips a week in delivering. There are few men, however, who have such regular routes, the majority of them having to depend on peddling, perhaps over the same route, but not to regular customers, and without fixed days or time on which to do this peddling.

The common custom is for farmer A to drive to town with a load of produce. He will leave his load and go to a grocery store and ascertain the prices which the grocer is charging for commodities which he has to sell. He then goes out through the town from house to house in an attempt to sell his produce, and asking practically the same price as the grocer. If he has a good day, he may sell all his produce, but often he crosses routes with other farmers and by the middle of the afternoon may be left with a considerable part of it unsold. His next move is to go to the grocer and offer his remaining produce for sale. It has by this time been picked over, and in many cases was in none too good shape at the start. The grocer realizes that the farmer is "stuck" with his produce; and may offer him a very low price for it. The grocer may resent the fact that the farmer has been to his customers. There is often

bitterness on the part of both and so long as this practice continues neither party may expect due consideration from the other.

There is a question as to whether either the consumer, the farmer, or the merchant gains anything from such a system. The consumer pays the farmer near the retail price, he is never certain that the farmer will appear at the proper time; but on the other hand, he does get fresh produce and has a right to reject poor quality goods on the spot.

The farmer receives about retail price for some of his produce, but if he has anything over, as is often the case, he receives much less than wholesale price for it and it takes him most of the day to dispose of his small load of produce.

The merchant loses sales when the farmers come in his distributing territory. He does not know how to buy because he cannot count on his trade. He may over-buy, taking a loss on hold-over produce, or he may under-buy, losing the opportunity for more sales. He has his overhead expenses going on every day. He is necessary to the consumer for at least ten months of the year. In the end the consumers must pay enough to support the retailer the year round even though they use him only ten months.

The retailers are obliged to keep a supply of vegetables and produce from day to day. Under the present system they cannot look to the farmer to furnish this supply. They, therefore, have to look to the wholesaler. Again the wholesaler cannot depend on the farmer to furnish the necessary commodities. It is his function to buy in car lots, and when a car load comes on the market it is sufficient for a period and during this period the local producer has no market for his small quantity.

The market situation is not at all satisfactory. Production must be increased before there is sufficient business on which to build a cooperative marketing organization. The most practical thing to look forward to seems to be a wholesale market, where the retailers could come and purchase their produce such as was offered by farmers from day to day.

Bulletin 213

January, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director
Morgantown

Comparative Tests of Certain Feeds in Rations for Pigs

By

E. A. LIVESAY and E. C. STILLWELL

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D.......President of the University
N. J. GIDDINGS, Ph. D.......Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr.......Agricultural Editor
JOHN C. JOHNSTON.......Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*Comparative Tests of Certain Feeds in Rations for Pigs**

For many years corn has been known to be deficient in the quality of its protein, and in certain mineral elements, particularly calcium. It is only within recent years, however, that experiments have shown that yellow corn is superior to white corn for hog feeding. Yellow corn, it is claimed, contains sufficient quantities of the fat-soluble vitamin (Vitamin A) for normal growth, while white corn does not.

This bulletin reports comparative tests of yellow versus white corn; wheat middlings versus buckwheat middlings; tankage versus fish meal; and also the value of feeds fermented with yeast versus non-fermented feeds for growing and fattening pigs.

To test the relative value of yellow and white corn in the production of pork, feeding trials were started during the winter of 1923 and repeated in 1924 and 1925. This publication gives the results of the three years of experimental feeding. The pigs averaged about 70 pounds each in 1923 and in 1924, and 80 pounds in 1925 at the time the feeding tests were started.†

Fig. 1.—Shaded areas show the sections of West Virginia where buckwheat is grown to a considerable extent.

*Submitted for publication May, 1926.

†The actual feeding and recording of data for these trials was done by W. N. McClung, herdsman.

In recent years, many requests have been received in regard to the value of buckwheat middlings, and in order to answer such inquiries, the experimental work herein reported was started. The feeding trials with buckwheat middlings were run on similar pigs, covered the same number of days, etc., as the yellow and white corn trials.

While the production of buckwheat in West Virginia is not very great, it is of sufficient importance in several counties to demand more information as to the feeding value of its by-products for hogs and cattle as compared with other concentrates. The more mountainous sections of the state, as shown in Figure 1, produce buckwheat to a considerable extent. According to the last census report, Preston county leads all other counties of the state; its annual production being approximately 200,000 bushels.

The reports of feeding trials with tankage and fish meal, and of the fermentation of the carbohydrate feeds with yeast are considered as preliminary, but have been included in this publication since the work was conducted in conjunction with the comparisons of yellow and white corn, and of wheat middlings and buckwheat middlings.

REVIEW OF LITERATURE*

In 1920, Steenbock and Boutwell *(8)*, in their work with rats discovered a striking difference in the vitamin A content of yellow and white corn. Following Steenbock's discovery, Morrison, Bohstedt, and Steenbock conducted a feeding trial with pigs to determine the relative values of white and yellow corn in producing pork. Russell and Morrison *(6)* have reported that these investigators found yellow corn to be superior to white corn, when fed with tankage since 16 percent more white corn than yellow corn was required to produce 100 pounds gain. Russell and Morrison *(7)* have also reported the same results for yellow and white corn in another feeding trial conducted by Morrison, Fargo, and Bohstedt. These investigators found yellow corn to be superior to white corn, when fed with tankage, as well as when supplemented with skim-milk. The pigs used in this work weighed from 50 to 60 pounds at the beginning of the trials, and were carried to 200 pounds. When tankage was used as a supplement to white and yellow corn (both lots self-fed), the yellow corn lot made an average daily gain of 1.06 pounds and required 447 pounds of feed per 100 pounds gain, while the white corn made 0.63 pounds daily gain and required 554 pounds of feed per 100 pounds gain. The lots receiving skim-milk as a supplement to corn also showed the inferiority of white

*All literature cited with respect to hogs refers to dry lot feeding.

corn. The white corn and skim-milk lot made practically as rapid gains as the lot fed yellow corn and skim-milk for a time, but finally nearly all the pigs died from what seemed to be pneumonia.

The Illinois Station *(4)* has reported that nine out of ten fifty-pound pigs died on a ration of white corn and tankage before reaching marketable age, while another lot on the same ration plus a small amount of cod-liver oil grew normally to a weight of 275 pounds.

A preliminary report of the Nebraska Station *(9)* showed yellow corn to have a feeding value slightly superior to that of white corn, when both were fed to pigs weighing from 67 to 114 pounds over an average period of 88 days. There were no indications of rickets developing in the lots fed on white corn, which, according to the report, was probably due to the fact that the pigs were fairly large when they were started on the two corn rations.

Lamb and Evvard *(2)* have reported that when a brood sow and her litter were fed upon a ration composed of white corn, oats, linseed oil meal, and a salt mixture containing lime, the pigs either died, or made little growth until vitamin A was added to the ration. These investigators worked with small numbers, and with pigs a part of which were heavily infested with ascari (round worm).

The same authors have also reported the results obtained in fattening pigs by feeding white corn as compared to yellow corn, in a ration similar to the one just mentioned. Very little difference was found between yellow and white corn for pigs of the weights used—approximately 130 pounds at the start.

Robinson *(5)* of the Ohio Station found buckwheat middlings to be inferior to tankage, when fed as a supplement.

EXPERIMENTAL METHODS

Pigs Used

The purebred pigs used in these feeding trials, composed of Duroc-Jersey, Poland-China, and Berkshire breeding, were divided into lots of 10, each year, as nearly equal as possible in regard to breed, size, and thrift. The pigs were approximately 14 weeks of age at the start of the trials, with an average weight of 70 to 80 pounds each. All sows and their litters were fed and handled in a similar manner, previous to the start of the feeding trials. In Lots I and III (1923), it was discovered that one pig in each lot was not eating and was falling off in flesh. These pigs were removed from the lots soon after the trial started. Upon inspection, the pig in Lot III was found to be blind, but there was no visible external or indicated internal condition of the pig in Lot I to warrant its going off feed.

Equipment

All lots were fed in metal troughs on concrete floors. The sleeping pens as well as the outside runways were also concrete floored, so that the pigs were never off concrete during the test periods. Sleeping quarters were kept well bedded at all times. The pens and runways for all lots were of equal size (pens inside, 8 by 24 feet and runways 12 by 24), and all lots were about equally exposed to sunshine.

Feeds and How Fed

Table 1 gives the chemical analyses of the feeds used, and also the analyses of similar feeds, as taken from Henry and Morrison's tables in their book entitled "Feeds and Feeding." The greatest variation in the analyses of any one of the feeds used over the three years occurred in the case of buckwheat middlings. The crude protein of this feed varied from 22 to 32 percent. This variation was due to the lack of standardization in the milling of buckwheat flour, and not to adulterations. All feeds were of good quality. The yeast fed in 1924 and 1925 was the ordinary granular form.

TABLE 1.—Chemical Analyses of Feeds Used Compared with Analyses of Similar Feeds as Given by Henry and Morrison in "Feeds and Feeding."

Feeds Used	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N. F. E.	
1923*						
Yellow Corn	9.65	1.50	9.07	2.13	73.78	3.87
White Corn	10.41	1.41	9.60	1.96	72.78	3.84
Wheat Middlings	10.90	4.21	16.59	5.60	57.60	5.10
Buckwheat Middlings	9.47	5.26	32.03	4.63	40.10	8.51
Tankage	9.50	20.17	58.51	1.46	4.80	5.56
1924*						
Yellow Corn	11.42	1.31	8.54	2.10	72.67	3.94
White Corn	10.78	1.78	8.33	2.28	73.22	3.61
Wheat Middlings	8.68	3.97	15.96	7.06	59.01	5.32
Buckwheat Middlings	10.84	3.74	21.93	4.42	53.56	5.51
Tankage	7.55	21.64	57.70	2.19	5.35	5.57
1925*						
Yellow Corn	12.58	1.29	11.18	2.38	69.45	3.12
White Corn	13.21	1.25	8.33	2.49	71.79	2.93
Wheat Middlings	11.01	4.91	16.66	9.18	53.18	5.06
Buckwheat Middlings	9.18	4.37	24.61	10.86	31.42	4.58
Tankage	7.71	21.60	59.36	1.20	2.33	7.80
Fish Meal	6.22	16.37	58.46	0.17	4.95	13 83
Henry and Morrison						
Corn, Dent, Grade No. 2	14.8	1.4	9.6	1.9	67.6	4.8
Wheat Middlings (Stand.)	10.5	4.4	17.4	6.0	56.8	4.9
Buckwheat Middlings	12.0	4.8	28.3	4.8	42.7	7.4
Tankage—60% percent	7.9	15.3	60.4	5.3	3.7	7.4
Fish Meal	10.5	28.1	51.4	....	....	8.3

*Chemical analyses of the feeds used were made by chemists of the West Virginia Agricultural Experiment Station.

The pigs were fed twice each day, morning and evening. The middlings and tankage (plus the mineral mixture for 1925) were fed as a slop and then followed by the shelled corn, with the exception of Lot IV in 1924 and 1925. The dry yeast, shelled corn, and middlings were mixed together, thoroughly saturated, covered with water, and allowed to ferment from 36 to 48 hours before feeding. Three-range electrical heaters were used to keep the mixture warm. The low heat was used in mild weather, the medium in fairly cold weather, and the high in very cold weather. Each heater was placed in a fifty gallon oil barrel containing water. The feed was mixed, put into large ten gallon pails, and placed in the barrels, so that a warm water bath surrounded the pails containing the feeds to be fermented. Three "rigs" of this kind were required to keep properly fermented feed on hand. This apparatus proved valuable in keeping the feed mixtures at a warm temperature of between 80 and 100 degrees Fahrenheit at all times.

The quantity of the rations fed was varied somewhat during the three-year period. In 1923 and in 1925 the pigs were given 4 pounds of feed daily, per 100 pounds live weight, but in 1924 they were fed 5 pounds. The pigs were weighed every 14 days, and the feed increased in accordance with the lot weights. The yeast was fed at the rate of 1 pound per 100 pounds of corn and middlings.

RESULTS

Tables 2, 3, and 4 give the results of the feeding trials.

Discussion of Results

No attempt has been made to figure the cost of production in this work, as will be seen from the data given in Tables 2, 3, and 4. Such costs are much more variable in a state like West Virginia, than they are in the corn belt states, which are close to the source of production of most hog feeds. The only explanation necessary in regard to the cost of the feeds used is, that the average price of buckwheat middlings for the three years was two dollars per ton more than wheat middlings. Farmers should apply their local feed prices, if they desire to calculate the cost of gains made on the various rations.

In 1923, white corn proved just as satisfactory as yellow corn, producing about the same daily gains and requiring almost exactly the same amount of feed to produce 100 pounds of pork. There were no indications that the pigs on the white corn ration were not as thrifty in every respect as those on yellow corn. In 1924 and 1925, when the pigs were fed for shorter periods (and in 1925 had a mineral

Fig. 2.—Duroc-Jersey pig (Lot III, 1924) after being given cod liver oil for a period of two weeks; still unable to rise without assistance.

TABLE 2.—Results of Feeding Trial, 1923, 98 Days, January 20 to April 28*.

ITEMS CONSIDERED	LOTS		
	I	II	III
Feed Mixture	Yellow Corn 300 Wheat Middlings 100 Tankage 20	White Corn 300 Wheat Middlings 100 Tankage 20	Yellow Corn 300 Buckwheat Middlings 100 Tankage 20
Nutritive Ratio	1:6.7	1:6.5	1:4.9
Number of pigs per lot	9	10	9
Initial lot weight	665.00	722.00	662.00
Average initial pig weight	73.88	72.20	72.55
Final lot weight	1485.00	1605.00	1729.00
Average final pig weight	165.00	160.50	192.11
Lot gains	820.00	883.00	1067.00
Average gain per pig	91.11	88.30	118.55
Average daily gain per pig	0 93	0.90	1.21
Feeds consumed:			
Corn	2520.45	2743.50	2959.20
Middlings	840.15	914.50	986.40
Tankage	168.03	182.90	197.28
Total feed per lot	3528.63	3[illegible]40.90	4062.88
Feed required per 100 pounds gain	430.32	434.98	380.77

*Feed mixtures and all weights are given in pounds.

mixture in addition), considerable trouble developed in the white corn lots. Both years about the seventieth day, several hogs in all white corn lots became wobbly and some went down, having every indication of rickets.

Three pigs in Lot II refused their feed on the seventieth day in 1924. They walked in a wobbly manner, appeared weak of back, and the following day went down and could not get up. These pigs were removed from the lot and fed a gruel containing cod liver oil. In two weeks they were up staggering about, but still going down in their hind legs occasionally and exerting all their strength to rise again. On May 2, these three pigs, still in a bad condition, were turned on alfalfa pasture (cod liver oil continued) and by June 16 two of them had apparently recovered. The other one, which never regained a normal condition, was left with weak hind legs, a back carried too low, and a curved spine. (See Figures 2 and 3).

The seven remaining pigs in Lot II of the 1924 test seemed to do fairly well from the seventieth to the eighty-fourth day, at which time they were shipped to market. In a short drive of from fifty to seventy-five yards, necessary in order to load the pigs in wagons, several of them developed striking symptoms of the trouble shown by the other three. No indications of this condition were shown by a single hog in either of the lots receiving yellow corn.

Fig. 3.—Two pigs (Lot III) which went down in 1924. This picture was taken after they had been given cod liver oil and had been on alfalfa pasture for 45 days. The pig at the left fully recovered but the other one did not. Note the low curved condition of the back of the pig at the right, which is the same one shown in Figure 2. The picture in Figure 2 was taken before the pig was placed on alfalfa pasture.

TABLE 3.—Results of Feeding Trial, 1924, 84 Days, February 8 to May 2.*

ITEMS CONSIDERED	LOTS			
	I	II	III	IV
Feed Mixture	Yellow Corn 300 Wheat Middlings 100 Tankage 20	White Corn 300 Wheat Middlings 100 Tankage 20	Yellow Corn 300 Buckwheat Middlings 100 Tankage 20	Yellow Corn 300 Wheat Middlings 100 Tankage 100 Yeast 1 pound per 100 pounds feed
Nutritive Ratio	1:7.0	1:7.1	1:6.0	1:7.0
Number of pigs per lot	10	10	10	10
Initial lot weight	708.00	704.00	720.00	720.00
Average initial pig weight	70.80	70.40	72.00	72.00
Fina lot weight	2012.00	1786.00	2140.00	2016.00
Average final pig weight	201.20	178.60	214.00	201.60
Lot gains	1304.00	1082.00	1420.00	1296.00
Average gain per pig	130.40	108.20	142.00	129.60
Average daily gain per pig	1.55	1.29	1.69	1.54
Feed consumed:				
Corn	3483.00	3162.00	3603.45	3488.89
Middlings	1161.00	1054.00	1203.15	1162.96
Tankage	232.20	210.80	240.60	234.55
Total feed per lot	4876.20	4426.80	5053.20	4886.40
Feed required per 100 pounds gain	373.92	409.13	355.85	377.04

*Feed mixtures and all weights are given in pounds.

TABLE 4.—Results of Feeding Trial, 1925, 70 Days, January 23 to April 3.*

ITEMS CONSIDERED	LOTS			
	I	II	III	IV
Feed Mixture	Yellow Corn 300 BuckwheatMiddlings 100 Tankage 20	White Corn 300 BuckwheatMiddlings 100 Fish Meal 20	White Corn 300 BuckwheatMiddlings 100 Tankage 20	White Corn 300 Wheat Middlings 100 Tankage 20 Yeast 1pound per 100 pounds feed
Nutritive Ratio	1:4.6	1:5.2	1:5.3	1:6.8
Number of pigs per lot	10	10	10	10
Initial lot weight	846.00	840.00	847.00	840.00
Average initial pig weight	84.60	84.00	84.70	84.00
Final lot weight	1602.00	1606.00	1609.00	1478.00
Average final pig weight	160.20	160.60	160.90	147.80
Lot gains	756.00	766.00	762.00	638.00
Average gain per pig	75.60	76.60	76.20	63.80
Average daily gain per pig	1.08	1.09	1.09	0.91
†Feed Consumed:				
Corn	2164.04	2156.04	2168.04	2080.04
Middlings	721.35	718.68	722.68	693.35
Tankage	144.21	....	144.47	138.61
Fish Meal	....	143.67	....	....
Yeast	....	....	....	29.11
Mineral	48.53	48.21	48.72	46.03
Total feed per lot	3078.13	3066.61	3083.92	2987.14
Feed required per 100 pounds gain	407.16	400.34	404.71	468.20

†All lots received the following mineral mixture: 5 pounds Acid Phosphate, 5 pounds Bone Meal, and 1 pound Salt. This mixture was fed at the rate of 1 ounce per 100 pounds live weight daily.

*Feed mixtures and all weights are given in pounds.

The data in Table 3 show that Lot I (fed yellow corn, wheat middlings, and tankage) made an average daily gain of 1.55 pounds and required 373.92 pounds of feed to produce 100 pounds of pork, while Lot II (fed white corn, wheat middlings, and tankage) made an average daily gain of 1.29 pounds and required 409.13 pounds of feed to produce 100 pounds of pork. The data for Lot II include the three hogs which developed rickets and had been out of the lot for 14 days. In other words, the hogs on white corn had made practically as economical gains as those on yellow corn up to the seventy-day period at which time the three hogs had to be removed from the lot.

At the beginning of the 1925 trial, each pig weighed approximately 14 pounds more than those at the start of the 1924 trial. The pigs in the 1925 trial received a mineral mixture in addition to the grain ration, yet the same trouble which was experienced the preceding year reoccurred. Three pigs in Lot II became wobbly and went off feed in the sixty-fifth day of the trial, and on the seventieth day two of these went down. On this date, two pigs in Lot III and three pigs in Lot IV were found to be staggering and practically unable to handle themselves. Neither the buckwheat middlings, fish meal, nor the mineral mixture prevented the trouble which occurred in 1924.

The condition of the hogs in Lots II, III, and IV made it necessary to discontinue the trial on the seventieth day. Those pigs in these lots which were in a bad condition were segregated, and they, with all the other pigs of these lots, were switched from white to yellow corn, and given a small quantity of cod liver oil with each feeding, for thirty-five days. All of the pigs improved and were in fairly good condition when shipped to market, which was thirty-five days after the bad effects of the rations containing white corn were noticed. The yellow corn ration proved satisfactory again in 1925 in carrying pigs, weighing around 80 pounds at the start, to a marketable weight.

Figure 4 shows the growth curves on all lots for 1925. Notice that white corn produced almost exactly the same gains as did yellow corn. It will also be noted from the data in Table 4 that Lots I, II, and III made 100 pounds of gain on about the same amount of feed.

No satisfactory explanation can be given as to why the pigs of Lot II in 1923, did not show any signs of the trouble experienced in all white corn lots in 1924 and 1925, however, several factors may have contributed to this result. The pigs were of practically the same breeding each year and were handled in a similar manner up to the time they were started on the feeding trials.

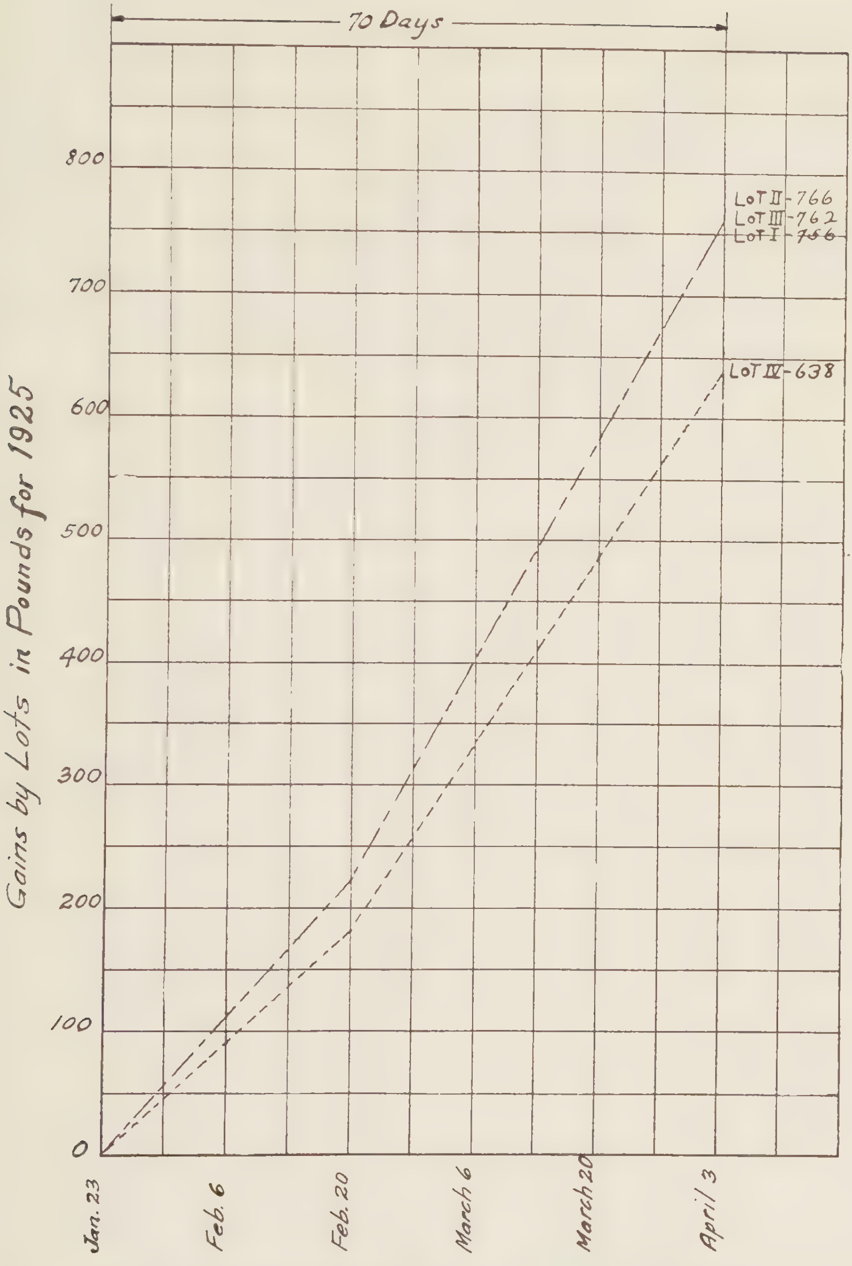


Fig. 4—This graph illustrates the growth made by the four lots of pigs in the 1925 trial. The growth made by Lots I. II, and III were so nearly equal for each of the five fourteen-day weigh-periods that only one curve could be shown without confusion.

In considering the feeding trials of 1923 and 1924, one might give as an explanation of the results obtained, the fact that a heavier ration was fed in 1924, which produced more rapid gains, thus causing the pigs to go down at an earlier date. The fact, however, that pigs did go down in Lot IV in 1925 on the same ration plus yeast in addition, tends to discredit this assumption. Lot IV (1925) was fed at the same rate per 100 pounds live weight as Lot II (1923) and it made almost an identical rate of gain. Another explanation of this point might be found in comparing the amount of sunshine during the 1923 trial with that during the 1924 and 1925 trials. Data regarding these conditions are not available, however, and, hence, this factor cannot be offered as an explanation.

Since in these trials the white corn produced almost as good gains in 1923 and as good gains in 1924 and 1925 (up to 70 days) as the yellow corn, the rachitic condition of the pigs fed white corn can hardly be attributed to a lack of vitamin A. The evidence tends to point to a lack of the anti-rachitic vitamin (vitamin D) in the white corn rations, which vitamin is essential for pigs of the size used.

The experimental work of Hess and Unger *(1)* shows rather conclusively that the cause of rickets in children is not associated with the fat soluble vitamin, since, in many instances, the disease developed in children being fed a diet containing an ample supply of this vitamin. Upon feeding babies, from five to nine months old, on a diet free from the fat soluble vitamin, they were unable to cause the development of rickets. McCollum *(3)* has shown that the ability of cod liver oil to correct or prevent rickets is not vested in the fat-soluble vitamin, but in a distinct vitamin—the anti-rachitic vitamin D.

Experimental evidence at the present time seems to indicate that vitamin D may, or may not, be closely associated with vitamin A.

Buckwheat middlings gave more rapid gains in weight than wheat middlings, when both were fed in conjunction with yellow corn and tankage, and reduced the amount of concentrates required to produce 100 pounds of gain (1923 and 1924). Buckwheat middlings seemed to be superior to wheat middlings in the 1925 tests, when fed with white corn and tankage, however, a portion of the ration containing wheat middlings was fermented with yeast, as has been mentioned. In 1923, Lot III made 100 pounds of gain on approximately 50 pounds less feed than Lot I, and in 1924 on approximately 18 pounds less. In 1925, Lot III made 100 pounds gain on approximately 64 pounds less feed than Lot IV.

The fermentation (by use of the granular yeast) of the corn and middlings in the ration fed Lot IV in 1924 did not improve it, so far as the rate or economy of gain was concerned, but the pigs did show nicer coats of hair. No definite comparison can be made on the value of yeast in 1925, as Lot IV was the only lot receiving wheat middlings in the ration. The pigs of this lot carried smoother coats, however, than the pigs of the other three lots.

In the single trial of fish meal against tankage, the two feeds proved about equal as protein supplements to corn and buckwheat middlings. The rate of gain was equal for Lots II and III (Table 4), and the feed required to produce 100 pounds of gain was only 4.37 pounds in favor of Lot II, which received fish meal.

CONCLUSIONS

1.—This study indicates that yellow corn is superior to white corn in fattening pigs weighing from 70 to 80 pounds at the beginning of the fattening period.

2.—Pigs weighing from 70 to 80 pounds make just as economical gains on white as on yellow corn for a certain period, which, in the 1924 and 1925 trials, seemed to be about 70 days.

3.—The pigs fed white corn developed a rachitic condition (2 out of 3 trials), while those fed the yellow corn did not.

4.—There is evidence that it was not the lack of the fat soluble vitamin in white corn, but the lack of the anti-rachitic vitamin (Vitamin D) which caused it to be inferior to yellow corn in these trials.

5.—Buckwheat middlings gave more rapid gains and required less concentrates to produce 100 pounds gain than standard wheat middlings, when each was fed in conjunction with corn and tankage.

6.—Buckwheat middlings is not as uniform a product as wheat middlings, consequently the purchaser should familiarize himself with the analysis of the product before giving it preference over wheat middlings.

7.—Fish meal was approximately equal to tankage as a supplement to white corn, buckwheat middlings, and a mineral mixture (one trial).

8.—The fermentation, for 36 to 48 hours, of corn and wheat middlings by the use of 1 pound of powdered yeast to 100 pounds of feed, did not increase the rate of gains or the economy of gains.

9.—If hogs are to be used for show purposes, yeast may have a place in their feed since in these tests it resulted in an improved condition of the hair, which gave the pigs a sleeker appearance.

10.—Neither buckwheat middlings, fish meal, nor the mineral mixture used prevented the rachitic condition, since it occurred in all white corn lots, in 1924 and 1925.

BIBLIOGRAPHY

(1) HESS, ALFRED F., AND UNGER, LESTER J.
1920. THE CHEMICAL ROLE OF THE FAT SOLUBLE VITAMIN: ITS RELATION TO RICKETS. Jour. Amer. Med. Assoc. 74:217.

(2) LAMB, ALVIN R., AND EVVARD, JOHN M.
1924. OBSERVATIONS OF THE VITAMIN A REQUIREMENTS OF SWINE. The American Society of Animal Production, Record of Proceedings of Annual Meeting, Dec. 1923. pp. 136-141.

(3) MCCOLLUM, E. V.
1923. PATHOLOGIC EFFECT OF LACK OF VITAMIN A AND OF ANTI-RACHITIC VITAMIN. Jour. Amer. Med. Assoc. 81:894.

(4) MUMFORD, H. W.
1922-1923. ANNUAL REPORT, Ill. Agr. Expt. Sta. p. 16.

(5) ROBINSON, W. L.
1921. SUPPLEMENTS TO CORN FOR FATTENING SWINE. Ohio Agr. Expt. Sta. Bul. 349, pp. 131-183.

(6) RUSSELL, H. L., AND MORRISON, F. B.
1920. NEW FARM FACTS. Director's Report, Wis. Agr. Expt. Sta. Bul. 323, pp. 10-11.

(7) RUSSELL, H. L., AND MORRSION, F. B.
1922. NEW PAGES IN FARMING. Director's Report, Wis. Agr. Expt. Sta. Bul. 339, pp. 125-128.

(8) STEENBOCK, H. AND BOUTWELL, P. W.
1920. THE COMPARATIVE NUTRITIVE VALUE OF WHITE AND YELLOW MAIZES. Jour. Biol. Chem. 41:81-96.

(9) UNIVERSITY OF NEBRASKA.
1924. WHITE VS. YELLOW CORN. Report of Animal Husbandry Department, University of Nebraska. Unpublished Data.

Bulletin 214 January, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director
Morgantown

The Effect of Height of Head on Young Apple Tree Growth and Yield

(A Preliminary Report)

Stayman Winesap trees in the spring of 1925, showing the comparative size and shape. The tree at the left was headed at one foot and the tree on the right at three feet. Notice the leaning trunks of the high-headed trees.

By

H. L. CRANE

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*The Effect of Height of Head on Young Apple Tree Growth and Yield**

(A Preliminary Report)

An experiment to determine the effect that the height of head of young apple trees has on growth and yield was started in the spring of 1916. For the purpose of this work, two varieties, Rome and Stayman, which are quite distinct in nature and type of growth, were used. One-year-old trees, carefully selected for uniformity of size and vigor, were planted. These trees were of the nursery grade, five to seven feet, and for the most part were approximately seven feet high. The root systems of the individual trees were pruned as nearly alike as possible before planting, removing mainly the broken roots and cutting off the rough, irregular ends.

Five pruning treatments, or heights of heads, were made of each of the two varieties. They were: (1) tops cut back to 1-foot trunk; (2) tops cut back to 2-foot trunk; (3) tops cut back to 3-foot trunk; (4) tops cut back to 4-foot trunk; and (5) tops cut back to 5-foot trunk.

In every case the length of the trunk left after pruning was measured from the point at which the tree was budded, to the apex. In an effort to obtain a length of tree trunk of 1, 2, 3, 4, or 5 feet, as the case might be, the trees were set so that the point at which they were budded was just at the surface of the soil.

The experimental work was conducted on a single row of trees through an orchard on the Horticultural farm at Morgantown. The orchard was planted with rows sixteen feet wide, and the trees thirteen feet apart in the rows. Two trees of Rome and four of Stayman were used for each height of head or pruning treatment, making thirty trees in all. The order of planting was two trees of Rome, then four trees of Stayman; this planting being repeated four times until the row was filled. In the spring of 1924, every other tree was removed to give the permanent trees more room. This left only one tree of Rome and two trees of Stayman for each method of treatment. An attempt was made to prune the trees uniformly, this, however, was difficult, due to the wide differences in the types of trees and their responses.

---

*Submitted for publication, May, 1926.

The methods of training and subsequent pruning were as follows: The trees were trained to the modified central leader form, having two scaffolds of four main branches each. The upper scaffold was approximately three feet from the lower one. The first season, the lower scaffold branches were selected and if they had made more than eighteen inches growth they were cut back to that length. The central leader was left from twenty to twenty-four inches long. All other branches were removed. Pruning the second season consisted of reducing the number of laterals on each main scaffold branch to two, all other shoots being removed. The central leader was headed back to about four feet from the first scaffold.

In the third and fourth seasons, the second scaffold was formed in the same manner as the first. The subsequent pruning was light and consisted mostly of a mere thinning out of thick places in the trees, and the removal of interfering or crossing limbs. No heading back was practiced after the fourth season. In all cases, it was the aim to give all the trees the same type and severity of pruning. This was impossible during the first two or three years in the case of the high-headed trees, because of their tendency to produce branches below the head. These shoots had to be removed in addition to the pruning necessary to train the trees. In this way, the high-headed trees received a little heavier pruning than the low-headed ones, for the first few years. Since that time, there has been practically no difference in pruning trees of different heights of heads.

CARE OF THE ORCHARD

The trees in the experimental plot received cultivation and cover crops each year. The cultivation consisted of five to ten treatments with a light draft harrow, a spike-tooth harrow, or disc, as the nature of the soil warranted. A cover crop consisting of a mixture of rye and hairy vetch was sowed during August. In the spring, the cover crop was plowed or disced under. An application of about three hundred pounds of 16 per cent superphosphate (acid phosphate) was made at the time of seeding the cover crop. In the spring of 1924, the trees received the only application of nitrogen, which consisted of four pounds of nitrate of soda per tree. This was applied when the trees were in bloom. The trees were kept thoroughly sprayed, at all times, to prevent any damage by insect pests or diseases.

METHODS OF OBTAINING DATA

In order to determine the exact amount of growth made each year by the trees of different heights of heads, the total lengths of the new shoots for the previous growing season were measured in the early spring. The trees were then pruned and the length of the one-year-old wood removed was measured. The new growth produced each year was measured for the first six years, after this, the only growth measurement made was the annual increase in trunk diameter.

When the trees in this experiment were planted, the diameters of their trunks were measured with calipers at a point approximately half way between the ground and the place where the heads were to be formed. This point was marked by painting a narrow band half way around the tree. The tree trunks were measured each year with the exception of 1918 and 1919.

To get a record of the fruiting of the trees, the number of blossom clusters was counted, and the yield of fruit was measured in total weight in pounds and in total number of apples produced.

PRESENTATION OF DATA

In presenting the data in this report, the individual, year-by-year tree records are given in two instances, while in all other cases only averages of the trees for each of the various treatments are recorded. In calculating the data for the annual length of shoot growth and the average annual increase in trunk circumference, Student's Method *(4, 5)*, which has been advocated by Love and Brunson *(3)* as an aid in interpreting similar data, was used. In the tables where this method of calculation was used, the column dealing with odds is important, as it gives a fairly accurate measure of the significance of the differences between treatments. Odds much below 30:1 indicate tendencies only, while greater odds approach absolute certainty, as a limit.

TREE GROWTH

The data presented in this report cover the first nine years after the trees were set, 1916-1924, inclusive, hence they are largely concerned with tree growth up to the age at which fruit production began.

Annual Shoot Growth

Table 1 shows the average total length of annual shoot growth per tree for the first six years. The low-headed trees, with one exception, made much more growth than those which were headed higher. This is true regardless of whether any one year's growth or all of the six

TABLE 1.—Length of Shoot Growth Produced by Individual Trees the First Six Growing Seasons Following Planting.

Varieties	Heights of Heads	Tree Numbers	Lengths of Shoot-Growths in Feet Produced by Seasons 1916	1917	1918	1919	1920	1921	Six-Year Total
ROME	1 foot	1		(died)					
		2	5.42	27.25	97.25	209.00	325.00	796.00	1,459.92
		Average	5.42	27.25	97.25	209.00	325.00	796.00	1,459.92
	2 feet	7	1.25	19.92	42.00	113.50	252.00	376.00	804.67
		8	7.00	31.58	53.66	129.00	297.00	345.00	863.24
		Average	4.12	25.75	47.83	121.25	274.50	360.50	833.95
	3 feet	13	2.92	12.75	35.58	86.50	207.00	244 00	588.75
		14	5.92	17.58	38 25	89.75	146.00	366.00	663.50
		Average	4.42	15.16	36.91	88.12	176.50	305.00	626.12
	4 feet	19	4.92	17.08	33.58	89.75	147.00	236.00	528.33
		20	1.42	8.00	20.25	45.50	115.00	179.00	369.17
		Average	3.27	12.54	26.91	67.62	131.00	207.50	448.75
	5 feet	25	1.00	8.00	14.83	43.50	84.00	157.00	308.33
		26	4.92	17.20	22.33	51.75	107.00	163.00	366.20
		Average	2.96	12.60	18.58	47.62	95.50	160.00	337.26
STAYMAN	1 foot	3	5.25	29.00	71.92	141.50	200.00	676.00	1,123.67
		4	6.33	25.66	59.50	162.50	311.00	657.00	1,221.99
		5	6.50	32.33	87.00	181.50	334.00	662.00	1,303.33
		6	2.75	16.92	45.66	129.00	262.00	447.00	903.32
		Average	5.20	25.98	66.02	153.62	276.75	610.50	1,138.08
	2 feet	9	2.83	23.75	56.66	148.00	303.00	594.00	1,128.24
		10	3.75	30.83	71.58	169.75	304.00	473.60	1,053.51
		11	3.75	21.16	44.50	138.75	302.00	391 00	901.16
		12	4.50	23.08	45.33	131.00	250.00	436.00	889.91
		Average	3.71	24.70	54.51	146.87	289.75	473.65	993.20
	3 feet	15	4.08	19.75	41.58	93.00	228.00	380.00	766.41
		16	4.83	17.25	56.16	133.50	275.00	357.00	843.74
		17	5.08	24.25	49.08	107.25	184.00	367.00	736.66
		18	4.83	23.50	51.92	106.00	307.00	471.00	964.25
		Average	4.70	21.19	49.68	109.93	248.50	393.75	827.76
	4 feet	21	2.16	8.25	20.33	48.25	80.00	164.00	322.99
		22	0.0	16.25	41.58	86.75	183.00	251.00	578.58
		23	0.0	3.08	13.42	42.75	95.00	199.00	353.25
		24	2.83	11.75	22.25	78.25	138.00	258.00	511.08
		Average	1.25	9.83	24.39	64.00	124.00	218.00	441.47
	5 feet	27	4.83	27.75	27.16	48.50	113.00	196.00	417.24
		28		(not same	variety)				
		29	13.25	27.00	32.33	86.00	142.00	229.00	529.58
		30		(not same	variety)				
		Average	*9.04	*27.37	29.75	67.25	127.50	212.50	473.41

*Most of this growth was produced near the ground and had to be removed.

years' growths are considered. During the first growing season the trees headed at one foot made more growth than those headed at two feet, but the amount of shoot growth decreased as the height of head increased. The one exception, as has been noted, was the Stayman trees headed at five feet. These trees made considerably more growth during the first three years after being set in the orchard than those headed at four feet. This was due to the fact that the trees headed at five feet produced a large part of their branches below the head, making it necessary to remove them. This lot of trees was the only one to form any number of branches below the head.

The Rome trees headed at the same height did not respond in the same way. During the third growing season the trees of this variety headed at one foot made about three times as much growth as those headed at five feet. The same ratio existed at the end of the six-year period. As the experiment progressed the difference in growth between the high-headed and the low-headed trees became more pronounced.

Data for total length of annual growth as influenced by the height of head have been calculated, using Student's Method, and are given in Table 2.

TABLE 2.—Comparison of Annual Growths as Influenced by Different Heights of Heads.*

Varieties	Year	Comparative Growths at Different Heights of Heads				
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet
ROME	1916	1.00	.76	.81	.60	.54
	1917	1.00	.94	.55	.46	.46
	1918	1.00	.49	.38	.27	.19
	1919	1.00	.58	.42	.32	.22
	1920	1.00	.84	.54	.40	.29
	1921	1.00	.45	.38	.26	.20
	Average	1.00	.67	.51	.38	.31
	Odds		800:1	2499:1	9999:1	9999:1
STAYMAN	1916	1.00	.71	.90	.24	1.74
	1917	1.00	.95	.81	.38	1.05
	1918	1.00	.82	.75	.37	.45
	1919	1.00	.95	.71	.41	.43
	1920	1.00	1.04	.89	.44	.46
	1921	1.00	.77	.64	.35	.35
	Average	1.00	.87	.78	.36	.74
	Odds		32:1	521:1	9999:1	5:1

*In this table, the average annual length of new growth produced on the trees headed at one foot has been taken as unity, and the growth of the trees of the other treatments has been compared with those headed at one foot.

The annual growth of the trees of various heights of head have been compared with those headed at one foot. In every instance but one, the odds were very significant in favor of the trees headed at one foot. This exception was in the case of the Stayman trees headed at five feet. As has already been pointed out the variation was due to the fact that these trees made most of their growth below the heads the first two years.

Severity of Pruning

Experiments have shown that pruning has a dwarfing effect on young trees. It is also true that the more severe the pruning the greater the trees are dwarfed. As the type and amount of pruning necessary to shape and train the trees with different heights of heads must vary to some extent, if any difference existed in pruning, the effect of the height of head might be overcome. In order to eliminate any influence of pruning, the trees were pruned as nearly as possible in the same manner and with the same severity (excepting the pruning necessary to keep branches from the trunks). Careful records were kept of the total length of one-year-old wood removed each year. These data are given in Table 3.

TABLE 3.—Average and Total Lengths of Wood Removed in Pruning Recorded by Varieties, Different Heighths of Heads, and Years.

Varieties	Heigths of Heads	Average Length of Wood Removed in Feet per Tree by Years					Total Wood Removed
		1917	1918	1919	1920	1921	
ROME	1 foot	15.2	75.6	118.5	152.0	224.0	585.3
	2 feet	17.3	32.2	68.5	153.5	216.0	487.5
	3 feet	6.3	24.7	52.7	99.0	191.5	374.2
	4 feet	8.5	19.9	36.7	71.5	127.0	263.6
	5 feet	10.9	13.2	23.8	56.5	90.0	194.4
STAYMAN	1 foot	14.6	37.6	88.4	126.0	282.3	548.9
	2 feet	15.4	30.7	88.5	146.0	269.0	549.6
	3 feet	14.3	30.7	68.2	124.2	213.7	451.1
	4 feet	5.9	16.8	32.3	56.2	102.5	213.7
	5 feet	24.1	22.6	41.2	58.0	124.0	269.9

From the data in Table 3 and those given in Table 1, the percentages of each year's growth removed by pruning during the first five seasons have been calculated and are given in Table 4.

TABLE 4.—Percentage of Each Year's Growth Removed by Pruning, 1917-1921 Inclusive.

Var eties	Heights of Heads	Percentage of Total Annual Growth Removed by Years					Percentage of Growth Removed 1917–1921
		1917	1918	1919	1920	1921	
ROME	1 foot	55.9	77.7	56.6	46.7	28.1	40.09
	2 feet	67.1	67.3	56.4	55.9	59.9	58.45
	3 feet	41.5	66.9	59.8	56.0	62.7	59.76
	4 feet	67.7	73.9	54.2	54.5	61.2	58.74
	5 feet	86.5	71.0	49.9	59.1	56.2	57.64
STAYMAN	1 foot	56.1	56.9	57.5	45.5	46.2	48.23
	2 feet	62.3	56.3	60.2	50.3	56.7	55.33
	3 feet	67.4	61.7	62.0	50.0	54.2	54.49
	4 feet	60.0	68.8	50.4	45.3	47.0	48.40
	5 feet	88.1	75.9	61.2	45.4	58.3	57.01

In the case of both varieties, the trees headed at one foot had the least amount of wood removed. The trees which were headed higher than one foot, with one exception, received practically the same severity of pruning. This exception was in the case of Stayman headed at four feet, which had about 7 percent less wood removed than did the other trees headed higher than one foot. The striking thing brought out in this table is that the trees headed at five feet required the removal of but little more wood to form the head at that height than was required for those headed at two feet. The Rome trees headed at two feet had approximately 1 percent more wood removed than those headed at five feet, while the Stayman trees headed at five feet required the removal of about 2 percent more wood than those headed at two feet.

The low-headed trees, in their first and second growing seasons, produced fewer and longer shoots than the high-headed trees. During the succeeding years, the growth produced on the main scaffold branches and primary laterals was distributed so much better on the low-headed trees that more wood could be left to advantage. The differences in the amounts of wood removed in pruning the trees of different heights of heads, however, would not account for the great differences obtained in shoot growth.

Weight of Wood Removed by Pruning

During the four-year period, 1922-1925 inclusive, the wood removed by pruning was weighed. These data are given in Table 5.

TABLE 5.—Average and Total Weights of Wood Removed in Pruning, Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Weight of Wood Removed per Tree by Years in Pounds				Total for Four Years	Average per Year
		1922	1923	1924	1925		
ROME	1 foot	9.50	12.20	12.40	17.30	51.40	12.85
	2 feet	3.75	3.95	4.70	4.00	16.40	4.10
	3 feet	2.12	2.85	3.25	3.00	11.22	2.80
	4 feet	1.50	1.80	3.50	2.10	8.90	2.22
	5 feet	1.37	2.40	2.65	1.60	8.02	2.00
STAYMAN	1 foot	6.37	7.35	7.76	9.80	31.28	7.82
	2 feet	6.50	7.00	7.12	10.70	31.32	7.83
	3 feet	4.62	7.15	7.05	10.20	29.02	7.25
	4 feet	2.18	2.17	3.77	4.45	12.57	3.14
	5 feet	2.25	3.55	3.65	....	....	....

*All pruning was done during the spring months each year.

The data presented in Table 5 show that the amount of wood removed was closely proportional to the growth the trees made during the first six growing seasons. The Stayman trees may be divided into two classes as to the severity of the pruning, those headed from one to three feet, and those from four to five feet. The trees headed at three feet were smaller at the time of this report (May, 1926) than those headed at two feet or one foot. Yet, for some unaccountable reason, the difference in pruning during the four-year period (1922-25) was not in proportion to tree size, as these higher headed trees were pruned almost as heavily as those headed lower.

The Rome trees headed at one foot had, due to their much larger size, much more wood removed from them than any of the others. These trees were probably better located than any of the others on account of a slight dip in the land, which caused the soil to have a higher moisture content and possibly greater fertility. These differences in pruning and in the soil were not sufficient, however, to influence greatly the growth or size of trees, as was shown by trees of the same varieties which grew in an adjacent row, sixteen feet away, and received the same culture.

Increase in Circumference of Tree Trunks

The annual increases in the circumference of the tree trunks were measured from the time the trees were planted. These data are given in Table 6.

The trunks of the high-headed trees were much smaller in circumference than those of the low-headed trees. The circumference of the

TABLE 6.—Comparison of Circumferences of Tree Trunks by Varieties, Heights of Heads, and Years.

Varieties	Heights of Heads	Tree Numbers	Circumferences at Planting in 1916	Circumferences of Tree Trunks in Inches by Years* 1916	1919	1920	1921	1922	1923
ROME	1 foot	1		(died)					
		2	1.13	1.26	5.87	8.50	11.25	14.00	16.12
		Average	1.1	1.26	5.87	8.50	11.25	14.00	16.12
	2 feet	7	1.19	1.29	4.50	6.25	8.37	10.12	11.75
		8	1.26	1.63	4.62	6.25	8.00	9.50	10.75
		Average	1.22	1.46	4.56	6.25	8.18	9.81	11.25
	3 feet	13	.91	.97	3.37	4.87	6.25	7.75	9.50
		14	.85	1.04	3.87	5.37	7.00	8.75	10.25
		Average	.88	1.00	3.62	5.12	6.62	8.25	9.87
	4 feet	19	1.00	1.10	3.87	5.50	7.12	8.50	10.25
		20	.85	1.04	3.00	4.50	5.75	7.00	8.50
		Average	.92	1.07	3.43	5.00	6.43	7.75	9.37
	5 feet	25	.88	1.13	3.25	4.02	6.37	7.62	9.50
		26	1.13	1.41	3.50	4.87	6.37	7.75	9.25
		Average	1.00	1.27	3.37	4.74	6.37	7.68	9.37
STAYMAN	1 foot	3	1.57	2.01	6.62	9.00	11.62	13.75	.....
		4	1.63	1.82	6.62	8.87	11.25	13.25	15.75
		5	1.50	2.01	6.62	9.12	10.62	13.50	15.75
		6	1.44	1.63	5.50	7.87	9.75	11.50	13.25
		Average	1.53	1.87	6.34	8.71	10.81	13.00	14.92
	2 feet	9	1.50	1.63	6.00	8.25	10.87	12.75	15.00
		10	1.60	1.92	6.50	9.00	11.37	13.25	15.50
		11	1.50	1.63	5.50	7.50	9.50	11.12	13.00
		12	1.32	1.41	5.75	8.00	10.12	12.12	14.50
		Average	1.48	1.64	5.93	8.18	10.46	12.31	14.50
	3 feet	15	1.32	1.57	5.25	7.25	9.62	11.50	14.00
		16	1.32	1.44	5.62	7.75	10.12	12.00	14.37
		17	1.16	1.29	4.50	6.25	8.00	9.25	11.00
		18	1.19	1.29	5.50	7.50	9.62	11.50	13.75
		Average	1.24	1.39	5.21	7.18	9.34	11.06	13.28
	4 feet	21	1.19	1.26	3.75	5.25	6.62	8.00	9.75
		22	1.16	1.26	5.00	7.37	9.62	11.37	13.50
		23	1.16	1.19	3.25	5.12	6.75	8.50	10.50
		24	1.32	1.35	4.50	6.25	7.87	9.25	11.00
		Average	1.20	1.26	4.12	5.99	7.71	9.28	11.18
	5 feet	27	1.07	1.38	3.50	5.12	7.25	9.00	11.25
		28		(not same	variety)				
		29	1.09	1.35	4.12	5.62	7.25	8.50	10.12
		30		(not same	variety)				
		Average	1.08	1.36	3.81	5.37	7.25	8.75	10.68

*All measurements were taken at the end of the growing season each year.

Rome Beauty trees in the spring of 1925, showing comparative size and shape. The tree at the left was headed at one foot, the tree in the center at three feet, and the one on the right at five feet.

tree trunks became smaller as the height of the head increased. From Table 6, it may be seen that the Stayman made larger gains in trunk circumference than the Rome, due to the more vigorous growth of this variety.

In Table 7 is given the average yearly increase in trunk circumference as influenced by the height of head of the trees. The total increase in the circumference of the trunk was greatest, on both varieties with the trees headed at one foot. The increase in trunk girth became less as the height of the head increased. When the differences between the trees headed at one foot and those headed higher were compared by Student's method, it was found that, in the case of the Rome, all the trees headed higher than one foot had made significantly smaller increases in trunk circumference than those headed at one foot. With the Stayman, however, significant odds were found only with those trees headed at four feet.

TABLE 7.—Average Increases in Trunk Circumferences Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Increases in Trunk Circumferences in Inches Recorded by Growing Seasons						Total Increase for Eight Seasons	Average Increase per Season	Odds In Favor of 1-Foot Head
		1916	*1919	1920	1921	1922	1923			
ROME	1 foot	.13	4.61	2.63	2.75	2.75	2.12	14.99	2.50	
	2 feet	.24	3.10	1.69	2.13	1.63	1.44	10.23	1.70	118:1
	3 feet	.12	2.62	1.50	1.50	1.63	1.52	8.89	1.48	132:1
	4 feet	.15	2.36	1.57	1.43	1.32	1.52	8.35	1.39	112:1
	5 feet	.27	1.10	1.37	1.63	1.01	1.69	7.07	1.17	38:1
STAYMAN	1 foot	.34	4.47	2.37	2.10	2.19	1.92	13.39	2.23	
	2 feet	.16	4.29	2.25	2.28	1.85	2.19	13.02	2.17	3:1
	3 feet	.15	3.82	1.97	2.16	1.72	2.22	12.04	2.00	11:1
	4 feet	.06	2.86	1.87	1.72	1.57	1.90	9.98	1.66	38:1
	5 feet	.28	2.45	1.56	1.88	1.50	1.93	9.60	1.60	19:1

*Includes growth for seasons of 1917 and 1918.

Volume of Top

In an attempt to show more clearly the differences existing in tree size and bearing surface, the height and spread of the trees were measured in the early spring of 1925. The distance from the ground to the lowest limbs was also measured. The tops of the trees were found to conform more closely to the shape of a sphere than to any other geometrical figure, as the trees had not borne crops sufficiently heavy to spread the tops. To calculate the volume of the tree tops, all of which may be considered potential bearing area, the distance from the ground to the lowest limbs was subtracted from the height

of the trees, which gave the diameter of the top in a vertical direction. This was then averaged with the width of the tree, which resulted in what was used as the diameter of the tree or sphere. The volume of the sphere was then calculated in the usual manner ($V=1/6\pi D^3$). These data are given in Table 8.

TABLE 8.—Heights, Widths, and Volumes of Trees as Influenced by Heights of Heads; Measurements Made in the Spring of 1925.

Varieties	Heights of Heads	Average Heights in Feet	Average Widths in Feet	Average Distances from Ground to Limbs in Feet	Average Volumes of Tops in Cubic Feet
ROME	1 foot	15.0	16.0	2.50	1515.08
	2 feet	12.5	11.0	3.25	543.45
	3 feet	12.5	9.5	4.00	381.70
	4 feet	13.0	8.0	4.75	280.31
	5 feet	13.5	8.0	5.50	268.08
STAYMAN	1 foot	15.50	16.75	1.25	1949.81
	2 feet	15.75	17.00	2.00	1901.11
	3 feet	15.62	17.00	3.12	1680.23
	4 feet	15.25	14.50	4.25	1085.23
	5 feet	(All trees removed at this time)			

The high-headed trees were several years behind the low-headed trees in actual size when the top measurements were taken in 1925. They were less stocky, less vigorous, and much less desirable. The lower the trees had been headed, the larger was the top, as shown by measurements of height and breadth, or total volume. Both varieties responded in the same way. The Stayman, being a more vigorous grower, made larger trees than the Rome, but the response to the height of head was the same.

BLOOM AND YIELD

As has been stated, since this report covers only the first nine years of the life of the trees after they were set in the orchard, it must necessarily deal largely with growth. The trees were still so young at the time this report was prepared that very little could be expected from them in bloom and yield of fruit.

The trees produced their first bloom in the spring of 1920, four years after they were set in the orchard. At this time, the number of blossom clusters was counted on each tree. This was continued for three more years. These data are given in Table 9.

It is interesting to note that the high-headed trees were the first to bloom, and that they continued to bloom more heavily than the low-headed trees. This is especially significant when the great difference in size of the trees is considered.

TABLE 9.—Average Number of Flower Clusters Per Tree Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Number of Flower Clusters per Tree by Years				Total 1920-23
		1920	1921	1922	1923	
ROME	1 foot	0	6.5	74.0	105.0	185.5
	2 feet	0	0.5	.5	32.5	33.5
	3 feet	0	2.0	13.5	15.7	31.2
	4 feet	3.0	2.0	1.5	20.0	26.5
	5 feet	3.5	12.0	14.5	164.0	194.0
STAYMAN	1 foot	0	0	.3	20.0	20.3
	2 feet	0	0.2	0	3.4	3.6
	3 feet	0	0	.5	12.5	13.0
	4 feet	0	0	.5	62.5	62.7
	5 feet	9.0	8.3	134.5	330.0	481.8

The only data obtained on yield of fruit were taken for the two crops borne in 1923 and 1924, for which the total weight of fruit was determined as well as the number of individual fruits produced per tree. These data are given in Table 10.

TABLE 10.—Yield in Pounds and Number of Apples per Tree Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Yield in Pounds per Tree by Years			Average Number of Apples per Tree by Years			Average Weights of Fruits in Pounds
		1923	1924	Total	1923	1924	Total	
ROME	1 foot	6.0	9.6	15.6	19.0	29.0	48.0	.32
	2 feet	2.2	0	2.2	4.0	0	4.0	.55
	3 feet	5.6	2.5	8.1	15.5	4.0	19.5	.41
	4 feet	0	1.5	1.5	0	3.0	3.0	.50
	5 feet	6.0	11.7	17.7	12.5	24.0	36.5	.48
STAYMAN	1 foot	2.4	3.7	6.1	5.5	9.0	14.5	.42
	2 feet	.9	18.7	19.6	2.0	53.5	55.5	.35
	3 feet	1.1	14.3	15.4	3.7	34.0	37.7	.40
	4 feet	5.3	27.4	32.7	11.0	65.5	76.5	.42
	5 feet	16.8			62.0			

The amount of fruit borne to the date of this report was too small to be of much value in determining the effect of height of head on fruit production. At the end of the first nine-year period, the yield had not been influenced to any appreciable extent by the height of the head. Practically all of the effect of the low heading of trees was that of producing trees of greater size and bearing area. Time alone will tell whether the trees of greater bearing area will produce crops significantly greater than those of the high-headed trees.

DISCUSSION

It is unfortunate that a larger number of trees was not included in this experiment. The data in regard to growth are so consistent, however, that it would seem that the effect of the height of head on the growth and yielding capacity of the trees is fairly clearly defined. This is especially true when it is considered that the results of this experiment substantiate those secured by Wiggans *(6)*, and Howe *(2)*, and the observations of Chandler *(1)*.

Wiggans *(6)*, in reporting on the growth made by similar trees which had been headed at different heights, says that, from the very beginning, the low-headed trees produced shoots which were much longer, and at the same time formed a larger number of branches than did the high-headed trees. Although no counts or measurements were made in the West Virginia experiment, it was observed that the low-headed trees produced more shoots, and also longer and stockier shoots, than the trees headed higher. This was especially true as the trees became older, since the trees headed at five feet grew in a manner similar to trees several years older; that is, the length of growth and the comparative diameter of the shoots were reduced.

Howe *(2)* used nine different varieties in testing the effect of high and low heads on growth and fruit production. He reported that, at the end of the first ten-year period, the low-headed trees were considerably larger in actual size, and more vigorous and stocky than the high-headed trees, and further that the low-headed trees of each variety bloomed and set fruit about one year earlier than the high-headed trees. Every variety but one yielded more fruit when the trees were headed low. He states that "the results indicate an economical advantage in the practice of low-heading due to increased yields and greater ease in orchard operations, and advances the opinion that, unless considerable care is taken in the formation of high heads, the larger amount of wood that must be removed may impair the vigor of the trees and check their development.

Under the conditions of the West Virginia experiments this opinion could hardly be true, as there was very little difference in the percentages of the total growth removed from the high- and the low-headed trees. Certainly the great difference in size of trees cannot be explained entirely on the basis of the dwarfing effect of pruning. There are apparently several factors operating, which taken together cause the wide variation in tree size.

Chandler *(1)* thinks that the large amount of pruning necessary to obtain a high head, and the injury which the young high-headed

trees suffer from bending about during early summer are responsible for the rather marked differences in the trees.

Numerous investigations in pruning have shown that the pruning of young trees dwarfs them to a degree dependent on the severity of the pruning. In this experiment, it was not necessary to prune the high-headed trees much more severely than the low-headed ones to form a high head. Certainly, the small difference between the amount of wood removed from the high- and the low-headed trees is too small to account for the differences existing in the size of the trees. It should be pointed out again that the trees in this experiment were planted as one-year old whips and were headed at the desired height at the time of planting. In this way, the main scaffold branches were produced at the height desired with a minimum amount of pruning. Had all the trees been headed at the same height at the time they were planted, and the high heads formed later by removing the lower limbs, more severe pruning would have been necessary. This, in view of the present knowledge of the dwarfing effects of pruning, would probably have caused wider differences in the size of the trees than actually resulted.

As an advantage of low-heading, it is claimed by some investigators that trees so headed do not grow as tall as if they had been headed higher. This claim is not borne out by the results of this experiment, since only a part of the bearing surface of the low-headed trees was lower than that of the trees headed higher. Considering the actual height of the trees, the low-headed ones grew as tall as those headed highest. The striking fact brought out by the data is the uniformity of the height of the trees regardless of the height of head. The greatest difference in the trees with different heights of heads was in the breadth and not in the actual height of the top. The low-headed trees, particularly of the Rome variety, developed much wider tops than those headed higher (See Table 8).

The height of head had no influence on the general type of tree as each variety maintained its usual characteristics. The high-headed trees had a tendency to bend and lean due to the influence of the prevailing winds. This was not so noticeable with the low-headed trees.

In so far as cultivation is concerned, no difference between the high- and the low-headed trees was found, other than that usually experienced with larger trees. The implements used in cultivation were those commonly employed in the average orchard. Other operations such as pruning and spraying were facilitated by the low-headed trees, and, no doubt, when the trees begin to bear heavy crops, harvesting operations will be easier.

CONCLUSIONS

From the data presented it must be concluded that low-headed trees make more shoot growth, and larger gain in trunk diameters than high-headed trees. Low-headed trees, as a result of this greater growth, have a larger bearing area than the high-headed trees. At the end of nine years, there was no appreciable difference in yield for the trees of different heights of heads. The trees were still too young, however, to expect much in fruit production. Judging by top area, it would appear that the low-headed trees will likely outyield the high-headed trees in the near future.

RECOMMENDATIONS TO GROWERS

There are considerable variations in the recommendations of horticulturists, and in the practices of commercial fruit growers, in regard to the height of heading young apple trees. Several important factors are considered in these recommendations and practices, such as ease of spraying, picking, pruning, thinning, prevention of winter injury to the tree trunk, and soil temperature.

The height at which the trees are headed should be determined, in a large measure, by the importance that the grower places on one or more of the foregoing factors. After all, over emphasis may be placed on some factor because of the grower's likes or dislikes.

If there is any difference, in tree growth and capacity to bear large crops, between high- and low-headed trees, the height of head which produces the largest tree in the shortest time should be given first consideration. It should be the aim and desire of the commercial grower to produce a tree as large as possible, which is capable of bearing maximum quantities of high grade fruit, in the least time. It is believed by the writer that this may be best accomplished by heading the trees low, preferably from one foot to two feet from the bud or graft.

REFERENCES CITED

(1) CHANDLER, W. H.
1925. FRUIT GROWING. pp. 282-283. New York.

(2) HOWE, G. H.
1923. GROWTH AND YIELD OF APPLE TREES PRUNED IN VARIOUS WAYS. N. Y. Agr. Exp. Sta. Bul. 500:16-22.

(3) LOVE, H. H., AND BRUNSON, A. M.
1924. STUDENT'S METHOD FOR INTERPRETING PAIRED EXPERIMENTS. Amer. Soc. Agron. Jour. 16:60-68.

(4) STUDENT.
1908. THE PROBABLE ERROR OF A MEAN. Biometrika 6:1-25.

(5) ....
1917. TABLES FOR ESTIMATING THE PROBABILITY THAT THE MEAN OF UNIQUE SAMPLE OF OBSERVATION LIES BETWEEN—OO AND ANY GIVEN DISTANCE OF THE MEAN OF THE POPULATION FROM WHICH THE SAMPLE IS DRAWN. Biometrika 11:414-417.

(6) WIGGANS, C. C.
1918. SOME FACTORS FAVORING OR OPPOSING FRUITFULNESS IN APPLE. Mo. Agr. Exp. Sta. Res. Bul. 32:49-50.

Bulletin 215 August, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

Lime For West Virginia Farms

Pulverizing Limestone on the Farm

By

D R. DODD

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, W. Va.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ------ President of the University
HENRY G. KNIGHT ....Dean of the College of Agriculture and Director of the Experiment Station
WALTER C. SCHNOPP, B. S. Agr. ------------------- Agricultural Editor
JOHN C. JOHNSTON --- Chief Clerk

AGRONOMY

R. J. Garber, Ph. D. — Agronomist
T. E. Odland, Ph. D. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, B. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
E. C. Stillwell, M. S. — Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

Henry G. Knight, Ph. D. — Chemist
R. B. Dustman, Ph. D. — Assistant Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
T. J. Cochran, B. S. — Junior Chemist

DAIRY HUSBANDRY

Ernest L. Anthony, M. S. Agr. — Dairy Husbandman
H. O. Henderson, M. S. Agr. — Associate Dairy Husbandman
Warren Gifford, B. S. Agr.†† — Junior Dairy Husbandman
G. M. Trout, M. S. — Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, M. S. — Junior Farm Mechanician
W. W. Armentrout, M. S. — Junior Farm Economist

HOME ECONOMICS

Ruth Buchanan, Ph. D. — Home Economist

HORTICULTURE

.... Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
H. E. Knowlton, Ph. D. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
Ernest Angelo, M. S. Agr. — Junior Horticulturist
L. F. Sutton, B. S. Agr.‡ — Assistant Horticulturist
Troy M. Currence, B. S. Agr.†† — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Assistant Plant Pathologist
L. H. Leonian, Ph. D. — Assistant Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman

SOILS

E. P. Deatrick, Ph. D. — Associate Soil Technologist

---

*In co-operation with the U. S. Department of Agriculture, Washington, D. C.
**In co-operation with the State Department of Agriculture, Charleston, W. Va.
†In charge of the Maggie Sub-Station, Maggie, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††On leave of absence.

Lime for West Virginia Farms

In this day when we are all thinking in terms of the community it behooves us to give more time and attention to those things which will be of most profit to all the people of the community. This is particularly true of the problem of liming our soils.

West Virginia Soils Need Lime

During recent years more than four thousand representative West Virginia soils have been analyzed by the West Virginia Agricultural Experiment Station. Of these, 95 per cent showed a lime requirement ranging from five hundred pounds to five tons per acre. Only 5 per cent showed a lime requirement of less than five hundred pounds. Even in the limestone sections of Berkeley and Greenbrier counties more than 70 per cent of the soils analyzed were found to be in need of lime in excess of five hundred pounds per acre. In brief, this means that the chances are 95 to 5 that one can produce better crops by an application of lime to the soil.

Lime on Crop Land

On many soils good clover crops can no longer be grown. Due to the acid condition which has developed in the soil, one finds growths of sorrel, poverty grass, redtop, cinquefoil, and briars, instead of the old time clover. Lack of a proper crop rotation with provision for the regular and systematic incorporation of organic matter, fertilizer, and lime has brought this about. Lime is the starting point for the rebuilding of these soils. There is abundant evidence that this rebuilding can be done at a profit. There are demonstrations of this in many communities of the state. Figures 1 and 2 show such a demonstration on the farm of D. W. Coffield near Wheeling, West Virginia.

The West Virginia Agricultural Experiment Station, and experiment stations in adjoining states have conducted experiments in the use of lime on which very careful data has been kept. Data from the sub-station at Maggie, West Virginia, in 1925 showed increases in yield of corn, wheat, and hay, resulting from the use of lime as given in Table 1.

Fig. 1.—Worn and Unproductive Clay Soil.

TABLE 1.—Yields of Corn, Wheat and Mixed Hay With and Without Lime at the Maggie Sub-Station in 1925.

Treatment	Yield in Bushels or Tons		
	Corn (bu)	Wheat (bu)	Hay (tons)
Lime*	67.0	22.0	2.32
No Lime	60.1	18.3	1.85

*Lime was applied at the rate of two tons of ground limestone per acre.

An experiment conducted at the Ohio Agricultural Experiment Station, gave results so closely in accord with West Virginia results that attention is here called to it.* The experiment was begun in 1900 and is still in progress. The crop rotation used is corn, oats, wheat, clover, and timothy. Table 2 gives the yields on both the limed and unlimed areas and the gain for lime. The application of lime has been the equivalent of two tons of ground limestone per acre for each rotation or every five years. The data given are for the five year period from 1914 to 1918 inclusive. Using a value of $1.00 for corn, $0.50 for oats, $1.50 for wheat per bushel, and $20.00 a ton for hay, a return of $16.00 for the equivalent of each ton of ground limestone used is obtained. Practice has shown that West Virginia farmers may expect similar results.

*Ohio Agricultural Experiment Station, Wooster, Ohio, Bulletin 336.

Fig. 2.—Soil Adjoining That Shown in Figure 1 and Formerly in the Same Worn Out Condition. A Bumper Crop of Sweet Clover Is the Result of Proper Applications of Lime and Acid Phosphate.

Will Lime Take the Place of Fertilizer

A good many farmers hold the impression that where lime is used an application of fertilizer is not necessary. This is wrong. Lime is not a direct fertilizer and is seldom needed as a plant nutrient, there being an abundance of lime in the soil for this purpose. Lime has a tendency to sweeten the soil, improve its mechanical condition, and make it a more favorable medium for the development of bacteria.

The operation of these factors increases chemical action rendering plant foods more available. However, they cannot increase the total supply of mineral element in the soil. Maximum yields cannot be obtained from the use of lime alone. This point is well shown in the Ohio experiment just referred to and summarized in Table 2. One series of plots received no treatment, another series received lime only, and a third series received both lime and fertilizer. The third horizontal line in Table 2 gives the yield for lime and fertilizer, and the fifth line gives the gain for fertilizer when used on limed land.

From Table 2 it is evident that lime pays even on unfertilized land but as shown by the figures at the bottom, maximum returns cannot be obtained without the application of fertilizer in some form in addition to lime.

TABLE 2.—Average Yield per Acre of Various Crops Under Different Treatments as Obtained at the Ohio Agricultural Experiment Station, Wooster, Ohio.

Treatment	Yield in Bushels or Pounds				
	Corn Bushels	Oats Bushels	Wheat Bushels	Clover Pounds	Timothy Pounds
Untreated	21.45	35.24	11.67	638	1339
Lime only	28.03	45.28	16.96	1338	2194
Lime and fertilizer	45.95	58.46	29.84	2297	2865
Gain for lime only	6.58	10.04	5.29	700	855
Gain for fertilizer over lime alone	17.92	13.18	12.88	959	671

Lime on Pasture Land

With the increase in land values, taxes, labor costs, fence costs, and miscellaneous expenses, and in many cases, the decrease in the carrying capacity of pastures, West Virginia farmers since 1900 have been rapidly approaching that point when the pastures no longer pay any profit. During recent years many farmers have seen th s and have taken steps to improve their pastures and thereby increase their returns.

In 1910 Mr. C. C. Lewis of Point Pleasant, West Virginia, started an experiment in pasture improvement. One-half of a pasture adjoining the highway was limed with one ton of burned lime per acre. Today, sixteen years after the application, anyone passing the field during the growing season can readily see the line marking the extent of the lime. The carrying capacity of the limed area was increased by 50 per cent or more and remained so for at least ten years. The difference is less evident today, but there is no doubt that each dollar invested in lime on this pasture has given excellent returns.

In 1923 an experiment was begun at the West Virginia Agricultural Experiment Station at Morgantown, one of the objects of which was to determine what increase might be expected from the use of lime on pasture land. The experiment is still in progress.

The land used for this experiment is a sandy loam hillside of the Dekalb series. It was so poor as to be practically worthless. This is shown by the fact that the untreated check plots produced only 429 pounds of dry grass per acre. These figures are probably

a little low due to the fact that the grass was mown. Stock might have nipped it a little closer. Where lime was used the yield was 723 pounds and where lime and acid phosphate were used the yield was 993 pounds per acre. This represents an increase of 68 per cent for lime alone and 131 per cent for lime and acid phosphate. Both the lime and acid phosphate were harrowed in lightly. Returns were not so good where harrowing was omitted. This was especially true for the acid phosphate. These and other tests and experiments leave little room for doubt concerning the general advisability of applying lime to many of our pastures, especially in connection with acid phosphate.

Kinds of Lime to Use

All liming material does not have the same neutralizing power; that is, 1120 pounds of freshly burned lime will neutralize as much soil acid as 2000 pounds of ground limestone. Liming recommendations are generally made in terms of ground limestone. The amounts of other materials which might be used in the place of 2000 pounds of ground limestone are:

Burned lime—1120 pounds
Hydrated lime—1480 pounds
Air slaked lime—2000 pounds
Marl (dry)—2000 pounds
Marl (freshly dug or wet)—2500-3000 pounds
Oyster shells (ground)—2000 pounds
Wood ashes—2700-3500 pounds

The more finely limestone is ground the more quickly will it neutralize an acid soil. Experiments indicate that for best results limestone should be of such fineness that 95 to 100 per cent of it will pass through a screen with ten meshes to the inch and 40 per cent through a screen with a hundred meshes to the inch.

All forms of lime should be bought on the basis of a guarantee of purity which is usually indicated by the sum of the percentages of calcium and magnesium oxides. To compare prices on two or more kinds of lime, divide the price per ton plus the cost of hauling by the percentage of total oxides. This gives the delivered cost per unit (1 per cent or 20 pounds) of oxide. The purity of raw or ground limestone and marl is frequently stated as percentages of calcium and magnesium carbonates. In this case it is necessary first to express the total percentage of these carbonates as the total percentage of

the corresponding oxides by multiplying by 0.56, before dividing the price per ton by the total percentage, in order to compare the prices of these materials with burned or hydrated lime.

For example let us suppose materials to cost per ton delivered at the farm as follows:

Ground Limestone	$6.00
40 per cent magnesium carbonate	
55 per cent calcium carbonate	
95 per cent total carbonates	
Hydrated Lime	$12.00
70 per cent total oxides	
Freshly Burned Unslaked Lime	$9.00
90 per cent total oxides	

In the case of ground limestone: 95 times .56 equals 53.2 per cent total oxides, $6.00 divided by 53.2 equals 11.2 cents cost per unit.

In the case of hydrated lime: $12.00 divided by 70 equals 17 cents cost per unit.

In the case of freshly burned lime: $9.00 divided by 90 equals 10 cents cost per unit.

On the basis of these assumed or arbitrary costs it appears that freshly burned lime is the cheapest. This may not be true in some cases in dealing with actual costs. One should also consider the agreeableness of handling. Freshly burned lime is of course objectionable in this respect. In the case of ground limestone and marl a guarantee of fineness should be required and taken into consideration in comparing different materials.

How much lime per acre? The answer to this question depends upon the acidity of the soil, the crops to be grown, and the cost of the lime. West Virginia soils vary in the amounts of lime needed from none to five or six tons of ground limestone per acre. Before investing in lime have a sample of your soil tested by your county agent.

Crops differ in their response to liming. The increases in per cent over the unlimed plots for the crops grown in the West Virginia and Ohio experiments previously mentioned have been as follows: clover 46, timothy 38, wheat 20, corn 18, and oats 12. Alfalfa needs more lime than red clover, while soybeans do reasonably well on soils

Amounts to Use

which are too sour to grow clover. For the general farm where it is desired to grow clover and where the cost of lime is not great a first application of two tons of ground limestone or its equivalent per acre with later applications of one ton every six years is about right for the average West Virginia soil. As a rule the first thousand pounds of limestone applied gives a larger net return than the second thousand pounds, the second gives more than the third, and so on. In many cases applications of a thousand pounds of ground limestone have brought good clover where none grew before. Where the cost of getting lime to the farm is excessive, small applications should be the rule. After the response to lime has been determined, larger applications may be made if desired.

Maximum returns, however, cannot be expected unless liming be made a definite part of the soil improvement program, and lime be applied as needed in connection with the use of organic matter and fertilizer in a good rotation.

There are some locations in West Virginia where ground limestone, refuse lime, or marl, may be obtained at a low cost. In such cases larger applications than those recommended above may be used.

On pasture land best returns are generally obtained when the application of lime is at the rate of about two tons of ground limestone or its equivalent per acre, together with three hundred pounds of acid phosphate. This is best "harrowed in" lightly where conditions permit, but may be used as a top dressing and left to incorporate itself. Where the stand of grass is not good it is advisable to reseed before harrowing with a good pasture mixture such as ten pounds Blue grass, five pounds Orchard grass, three pounds Red top, two pounds Japan clover, and two pounds White Dutch clover.

When and How to Apply

Probably the best time to apply lime on crop land is when one has time to apply it and the condition of roads and fields make hauling easiest. This is generally after harvest on sod lands. However, where light applications are being made or where lime is being used for the first time better results may be obtained by putting the lime on plowed ground before harrowing. Thus the lime may

Fig. 3.—Clover Demonstration on Farm of Jesse Bean, Hardy County. This Plot Received no Lime.

be more thoroughly incorporated in the soil. Suitable times for such applications are in the fall before seeding winter grain and in the spring before corn is planted.

On pastures early spring applications give good results.

The use of a spreader, preferably one of the forced-feed type is the easiest and best method of spreading most forms of lime. There is also a spreader that may be attached to the rear of the ordinary farm wagon that some farmers like especially for refuse lime which does not feed well through the ordinary forced-feed type. Limestone, marl, and refuse lime, are frequently spread with a manure spreader. This is easily accomplished by first putting on the bed of the spreader a layer of straw or manure.

Unground burned lime (lump or stone lime) is preferably placed in piles in the field to slake and then spread with a shovel. One bushel of lime per pile with piles forty feet apart each way will make an application of one ton per acre.

It is customary with this practice to cover the piles with a little soil for two or three weeks when the lime will be found to have taken on a finely powdered condition and is easy to spread.

Home-made Spreader

There are a number of good spreaders now on the market and generally it is cheaper in the long run to buy one than to attempt to make one at home. The farmer who is skilled with tools, how-

Fig. 4.—This Plot Adjoins that Shown in Figure 3 and Received Ground Limestone at the Rate of Two Tons per Acre. The Girl in This Picture Is on Her Knees.

ever, and is convenient to a blacksmith shop can make a very satisfactory spreader and probably save some money. The following directions are given by Dr. Cyril G. Hopkins (deceased), of the Illinois Agricultural Experiment Station.*

"Make a hopper similar to that of an ordinary grain drill, but measuring 8 1/4 feet long with sides at least 20 inches wide and 20 inches apart at the top. The sides may be trussed with 3/8 inch iron rods running from the bottom at the middle to the top at the ends of the hopper. Let the bottom be 5 inches wide in the clear with 2 inch holes 5 inches between centers. Make a second bottom to slide under the first on straps of iron 10 inches apart, which should be carried from one side to the other under the hopper to strengthen it, also with holes to register. Both bottoms may be of sheet steel or the lower one may be of hard wood, reinforced with strap iron if necessary.

"To the lower and movable bottom attach a V-shaped arm projecting an inch from under the hopper, with a half-inch hole in the point of the V, in which drop the end of a strong lever, bolting the lever loosely but securely to the hopper with a single bolt, and fasten to the top of the hopper a guide of strap iron in which the lever may move to regulate the size of the opening by sliding the lower bottom. Make a strong frame for the hopper, with a strong, well braced tongue.

"Take a pair of old mowing machine wheels of good size, and with strong rachets in the hubs, and fit these to an axle of suitable length (about 10 feet) and 1 3/8 or 1 1/2 inches in diameter. The axle should be fitted with journels bolted to the under side of the frame. Make a reel to work inside the hopper by securing to the axle, 10 inches apart, short arms of 3/8 inch by 3/4 inch iron and fastening to these arms four slats or beaters of 5/8 by 3/4 inch iron about an inch shorter than the inside of the hopper, the reel being so adjusted that the beaters will almost scrape the bottom but will revolve freely between the sides. The diameter of the completed wheel is about 5 inches and it serves as a force feed."

*Cyril G. Hopkins, "Ground Limestone for Southern Soils," page 14.

Commercial Sources of Lime

Generally it is possible for commercial lime companies to produce a cheaper and better liming material than can be made at home. It is, therefore, advisable to first investigate the commercial sources. A list of commercial firms supplying lime to farmers in this state may be had by application to the Agricultural Extension Division, College of Agriculture, Morgantown, West Virginia.

Home Production of Liming Material

Many West Virginia farms are a considerable distance from the railroad. This necessitates a long haul from the railroad to the farm. This long haul, frequently over bad roads, together with freight charges make the cost of commercial lime so high that home production is more advisable. This is, of course, conditioned upon an available supply of good limestone.

The home production of pulverized limestone is more or less common in many sections of the state. A careful checking of all items of expense indicates that the average cost of such production is probably close to $3.00 per ton.

A few years ago the Ohio Experiment Station made some tests in which they were able to produce home pulverized limestone at slightly more than $2.00 a ton. Under present conditions in West Virginia such a low cost is quite the exception.

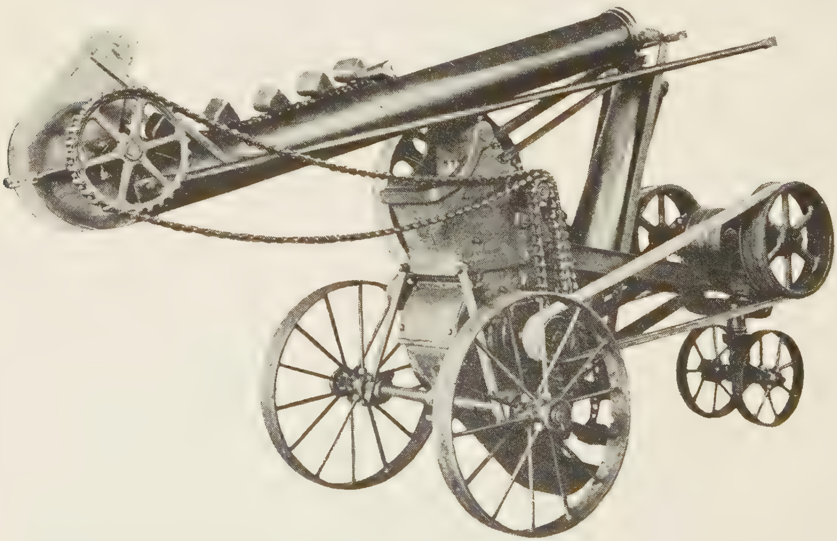


Fig. 5.—A Good Portable Pulverizer for Individual or Community Use. Capacity 15-20 Tons per Day. Power Required 8-16 or 10-20 Tractor.

The home product is generally not quite so good as the commercial product but is very satisfactory and numerous farmers report excellent results from its use. The chief drawback to home pulverizing is in the cost of equipment and the little use of it during the greater part of the year. This can be largely overcome by one man pulverizing for the community or by the community purchasing and operating the equipment. A list of manufacturers of pulverizing machinery will be furnished upon application to the Agricultural Extension Division, College of Agriculture, Morgantown, West Virginia.

Building and Burning the Lime Stack

The lime stack is intended for use where the more permanent draw kiln cannot be constructed to advantage, or where only a limited suppiy is desired for a year or two.

To build a lime stack, first lay down a rectangular foundation of logs and poles (up to fifteen inches in diameter) in regular order side by side large enough to hold the stone and coal. When finished the stack should be not more than eight feet high nor more than twenty feet wide. If a larger stack is desired, increase the length. A few feet in from each end or side (depending on direction in which logs are placed) leave a couple of the logs a little farther apart than the others and fill in with finer wood and kindling. These spaces are to serve as flues to carry the fire through the stack. At the ends of each flue add more kindling and cover each by setting two stones on edge with a third over the top. This covering is to prevent dirt and coal from falling down and closing the ends of the flues where the fire is to be started. Place over this foundation plenty of dry material, such as fence rails, chips, corn cobs, and brush. For general arrangement of the foundation, see Figure 10.

Next put on a layer of limestone about three inches deep and made up of pieces not more than three inches in diameter. This layer should come within a few inches of the outside of the wooden foundation. Cover the stone with just enough coal to hide it, fine coal being preferred. Continue alternating layers of stone with layers of coal as follows:

Courses	Thickness of Stone Layer in Inches	Diameter of Stone in Inches
First	3	3
Second	5	3
Third	8	4
Fourth	10	4
Fifth	12	6
Sixth	12	7

Fertilizer and Lime Plots on One of the Agricultural Experiment Station Farms, Morgantown, West Virginia

Fig. 6.—No Treatment; 100 Pounds Hay per Acre.

Fig. 7.—Lime Only; 750 Pounds Hay per Acre.

Any additional layers should be the same thickness as the last As the stones become larger toward the top a greater proportion of coal will be required to cover them; therefore, the thickness of the layer of coal should be reduced so as to have the same ratio of coal to stone as in the first layer. The area of each succeeding layer on the stack should also be reduced and no large stones should be used near the outside. Finally, a thin layer of coal should be put over the outside, and the stack should be banked with from five to nine inches of earth from the ground up one-third to one-half the height of the stack. Care should be used not to close or destroy the stone projections of the flues.

Size of Stack to Build

The size of the stack will, of course, be determined largely by the amount of lime desired. One long ton of coal used in a large

Fig. 8.—Lime and Fertilizer; 5800 Pounds Hay per Acre.

Fig. 9.—Lime and Manure; 7400 Pounds Hay per Acre.

stack will produce about three and a half tons or ninety bushels of stone of "caustic" lime. In a small stack forty bushels of coal may be required to produce a hundred bushels of lime. Therefore, if it is desired to produce fifty tons of lime about fifteen long tons of coal will be needed. In volume, a stack of this size, will require about 420 bushels (165 wheelbarrowfuls of 200 pounds each) of coal and 1470 bushels (600 wheelbarrowfuls of 300 pounds each) of limestone. A stack with a foundation 16 by 20 feet will produce 500 bushels. From these figures one may readily determine the size of the stack desired.

Burning the Stack

When ready to fire, pour a liberal quantity of kerosene on the kindling in the two flues on the windward side and set on fire. As soon as the fire is well started close the unused flues at the opposite end.

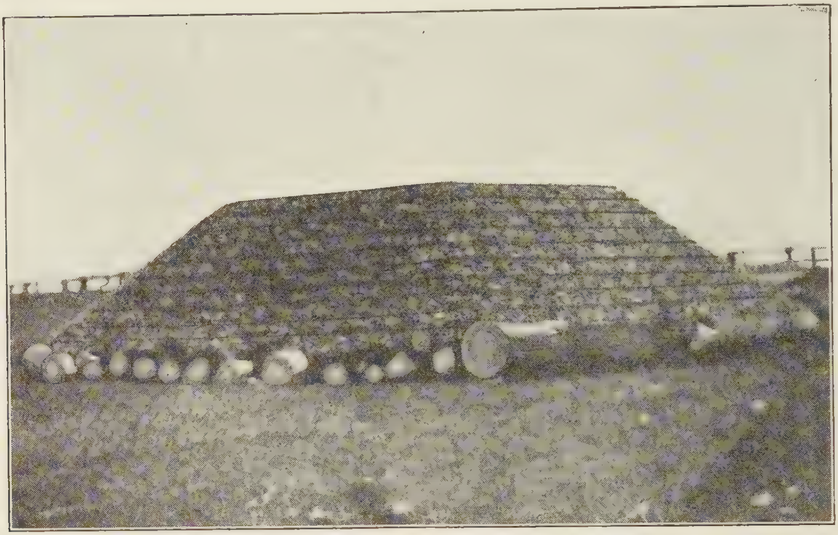


Fig. 10.—The Lime Stack Ready for the Covering of Fine Coal.

Loose soil should now be made in readiness along the sides of the stack and as the fire approaches the uncovered portion near the top of the stack throw on more dirt, keeping the covering just ahead of the fire until the entire stack is covered. Also watch for and promptly cover any cracks resulting from settling. If the stack burns too rapidly bank it with more dirt.

After the stack has finished burning and the lime is cool enough to haul, it may be taken to the field and placed in small piles to slake. After slaking it is ready to spread. A bushel of this stone lime weighs eighty pounds and from this the rate of distribution can readily be determined. A couple of shovelfuls of dirt thrown on each pile when put in the field will absorb much lime dust and make spreading more agreeable. If more convenient, the lime may be water-slaked in the stack, and then spread directly when hauled to the field. This is particularly desirable in case a spreader is to be used. Proper slaking will require from four to eight barrels of water depending on the size of the stack. This should be poured in openings made in the top of the stack.

Fig. 11.—A Type of Wood Burning Lime Kiln now Largely Replaced by the Stack.*

Construction of the Lime Kiln

The permanent lime kiln is particularly adapted to sections that have limestone and coal convenient and where it is desired to produce a considerable quantity of lime each year for a period of three or more years. The initial cost of the permanent kiln is greater than that of the lime stack but production is easier and cheaper than with the stack.

To construct such a kiln in which either coal or coke alone or either of these in combination with wood are to be used as fuel, select a hillside as near the fuel and limestone supply as possible. The ideal location is where the stone is above the site selected and can be worked down hill to the kiln and the fuel can easily be gotten to the kiln (see Figure 12). Dig back nearly horizontally (a slope of one inch to the foot makes it much easier to remove lime when drawing) into the hill so far as is necessary to get a vertical distance to the surface of about 15 feet. If this is impossible filling in above the kiln later will give the same advantages. The excavation should be about eight feet wide from the top down to a distance

*For more complete description of this type of kiln see Extension Circular No. 174, College of Agriculture, Lexington, Ky.

of seven feet from the bottom (see Figure 13, line AA). From this point down it may be gradually narrowed in from the back and rear half of each side till a width of about four feet remains at the base, as shown in Figure 13, line BB. A circular hopper (the kiln proper) resembling an inverted jug is to be constructed in this excavation, the back corners, therefore, need not be dug out.

Within the limits of the base as shown in Figure 13, line BB, dig a ditch six inches deep at the rear of the excavation and twelve inches deep at the front and in this begin a wall (see Figure 14). The depth is greater in front to avoid the effect of frost. Continue the ditch and wall across the front and back toward the hill as shown in Figure 14. The thickness of the wall and other dimensions will be determined somewhat by the material used and size and location of kiln, but for greatest convenience, the enclosed area as shown in Figure 14, should not be less than, and approximately as follows: A to B and C to D each = 24 inches; A to C and B to D each =36 inches; C to E and D to F each=8 inches; E to G and F to H each=78 inches; G to H=60 inches; G to I and H to K each=66 inches; and I to S and K to M are determined by the grade of the hill. When this wall has been brought on a level with bottom of the main excavation, place in the back of this V shaped opening and sloping toward the front a piece of boiler plate so as to rest on the ground and lap over the edge of the wall at the rear and both sides and reach forward four feet or more. Continue the wall on top of this boiler plate twenty-four inches where heavy stones or iron bars should be placed across the opening from C to D (see Figure 12). Build the wall twelve inches higher but this time across the bars at C-D leaving the section C-A-B-D untouched. Now drop back toward the front of the opening twelve inches from where the first bars were placed and lay others in the same manner (see Figure 12). Again add to the wall but build only to the second set of bars and then across these. Continue this building and dropping back, making the distance a little greater each time until a last set of bars are placed across the opening about six to seven feet from the ground at G-H. Then build across these and continue the wall to the height of the kiln as shown in Figures 12 and 14. It will be found advisable in most cases to build the interior, or hopper, of the kiln at the same time as the outside retaining wall. To do this begin at the twenty-four-inch square opening left when the first bar was placed across the opening through which lime is removed and build a hopper shaped like an inverted jug, the greatest bulge of which

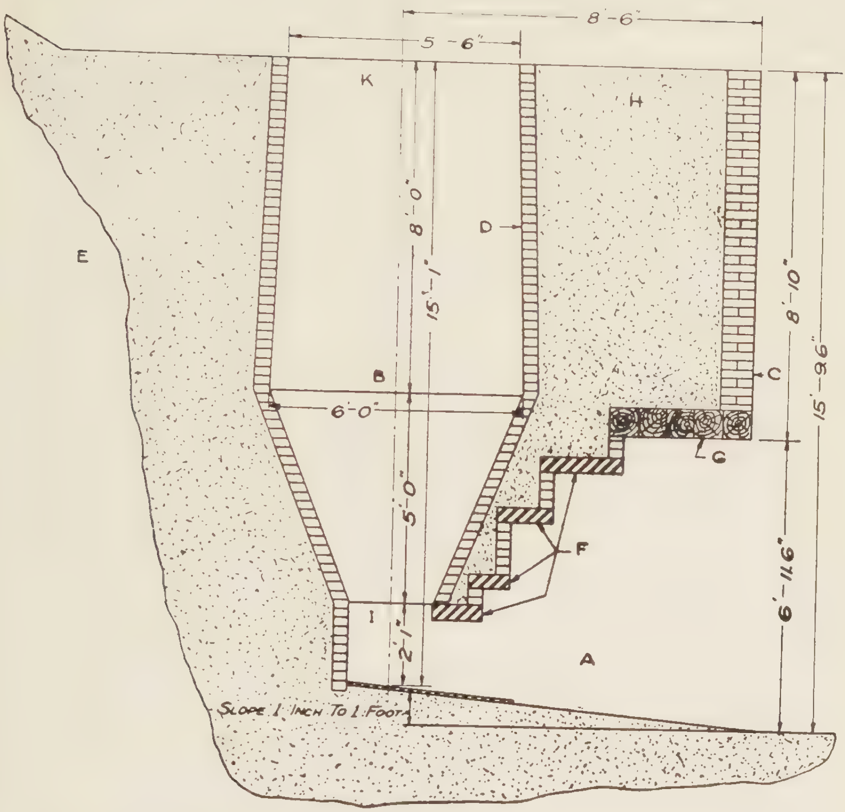


Fig. 12.—Vertical Section of Kiln.

A. Passage to mouth of hopper through which lime is removed.
B. Hopper or kiln proper.
C. Front retaining wall of any type of stone.
D. Fire brick or sand stone lining to kiln.
E. Hill serving as back retaining wall.
F. Iron bars supporting ceiling over passageway.
G. Wood beams serving same purpose.
H. Dirt filling between kiln and front retaining wall.
I. Mouth of kiln through which lime is removed.
K. Opening at top through which stone and fuel is fed.

will come about seven feet from the boiler plate (see Figure 12). The hopper should be about five and a half to six feet in diameter at the greatest bulge, five to five and a half feet at the top, and have an opening twenty-four inches square at the bottom. As the walls of the kiln are built up dirt should be filled in and packed hard between the

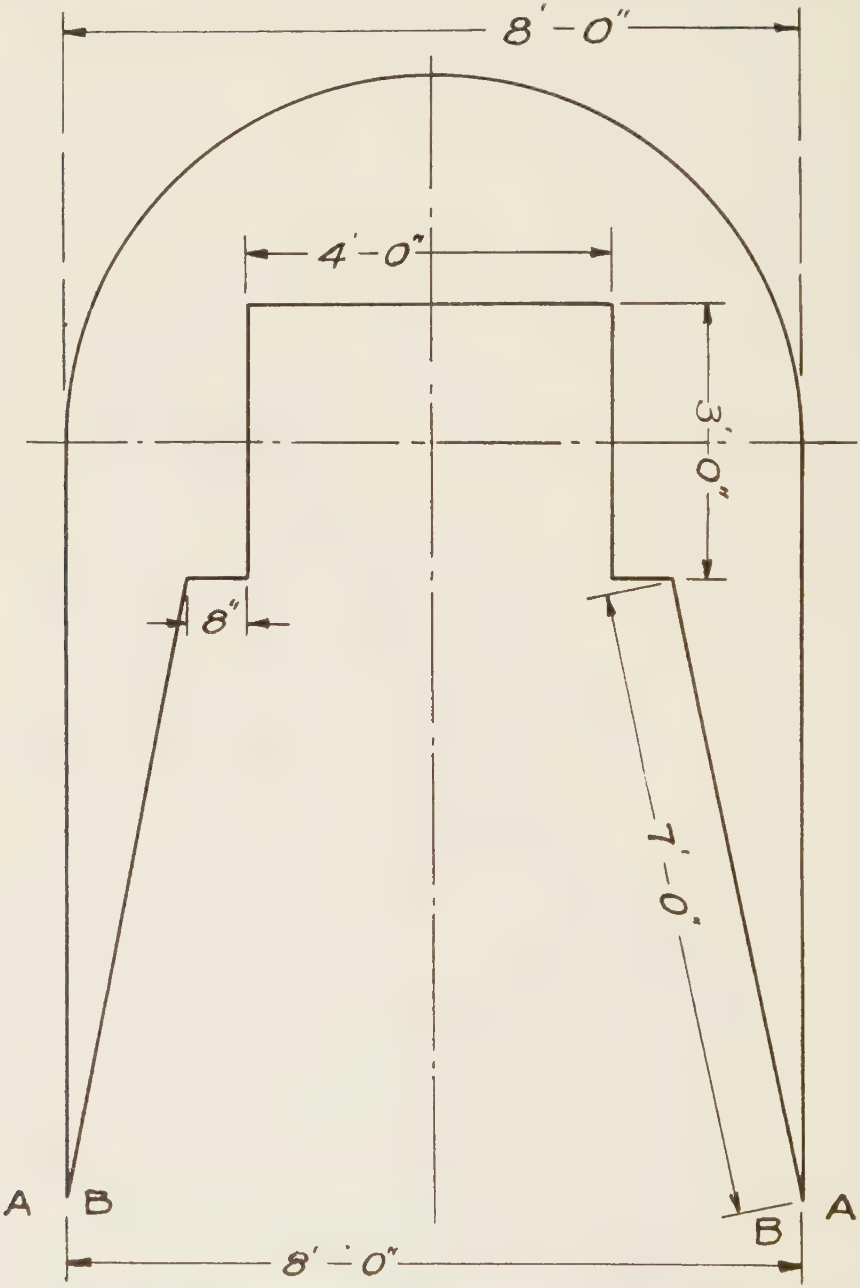


Fig. 13.—View of Excavation. Line AA Shows Outline of Excavation from Surface Down to Seven Feet from Base. Line BB Shows Outline of Base.

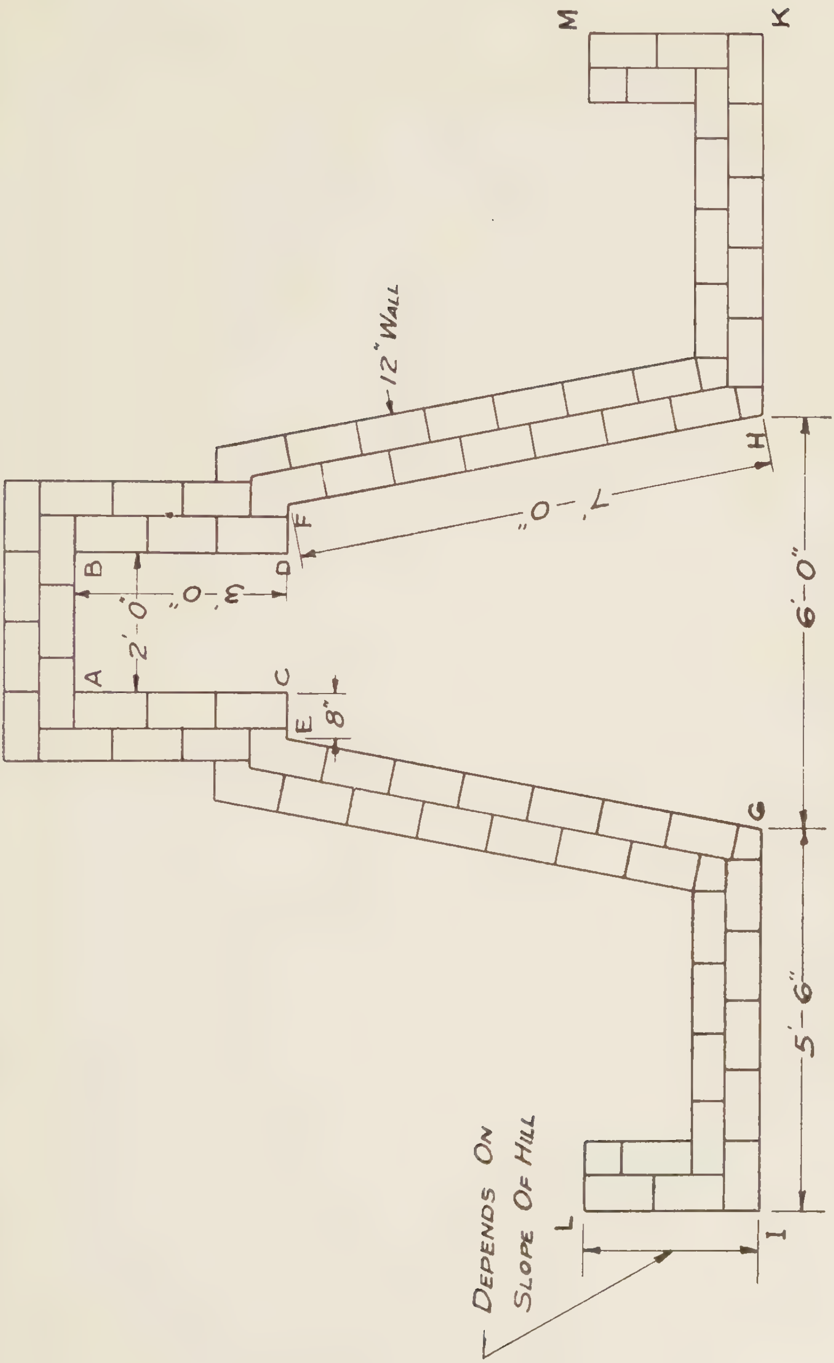


Fig. 14.—Foundation Wall of Kiln Constructed in and About Excavation Shown in Figure 13.

hopper and outside retaining wall. When these have been brought to the desired height the kiln is completed. The greater the height of the kiln the greater will be its daily capacity. Variations from the above dimensions will make no material difference if the opening at the base is kept large enough and the dimensions are kept in proportion.

A cheaper and more temporary kiln can be constructed after this same plan by substituting logs for stones in the front and side wall, as shown in Figure 15. The kilns shown in this figure are not over ten feet high.

Sandstone or fire brick must be used in the hopper of the kiln and about the mouth, since limestone would soon burn out. For this purpose about 4000 standard fire brick for a nine-inch lining will be required. The standard size of a fire brick is 2½ by 4½ by 9 inches. About 800 pounds of fire clay to each 1000 bricks will also be required.

Burning the Kiln

The permanent kiln constructed, the next step is to prepare the fuel and stone and fire it.

In starting the kiln observe the following steps.

1.—Put a generous supply of kindling in the bottom of the kiln.

2.—On top of this place six feet of wood (about one cord).

3.—Put on a layer of six inches of limestone broken into pieces the size of a quart cup or smaller.

4.—Add just coal enough to cover the stone.

5.—Put on another layer of ten inches of stone.

6.—Add coal as before.

7.—Put on twelve inches of stone.

8.—Add coal as before and continue to alternate as in steps 7 and 8 until the kiln is full. Fire the kiln and keep it full by continuing to alternate as in steps 7 and 8.

In a kiln the size here described 1¼ to 1½ tons of coal will turn out 100 bushels of stone lime (quicklime) equivalent to about 6¾ tons of hydrated lime. One ton of coke will take the place of 1½ to 1¾ tons of coal.

Wood may be used to advantage with the coal or coke but cannot be used alone in this type of kiln since wood burns too rapidly. In a kiln of this size, lime should be drawn every three of four

Fig. 15.—Temporary Lime Kilns in Use in Greenbrier County, West Virginia.

hours to get the greatest production. No evil effects other than loss of time will result, however, by less frequent drawings. If it is not desirable to keep a man at the kiln over night, or over Sunday, fill the hopper well up and shut off draft by closing the opening at the base.

In case the stone comes down unburned when drawing, cut off some of the draft and burn slower. If this does not correct the trouble add more fuel. In case over burned stone comes down increase the draft, and if necessary, reduce the fuel. When through burning empty the kiln or the slaking lime will burst it.

The Construction and Burning of Kilns When Wood Is Used as Fuel

There are several types of kilns in which wood can be used as fuel. Some of these wood kilns are modifications of the form just described for coal. Two fire boxes are built in from opposite sides of the kiln along the slope of the hill and open into the hopper just below its largest diameter. These fire boxes should be about two and a half feet wide by three feet high with an opening into the kiln of the same size. A grate should be fitted into the bottom of these boxes so that the ashes will drop through and can be removed. This also gives much better draft and heat. The wood kiln, however, is not advisable or practicable in West Virginia except in rare cases.

SUMMARY

The analyses of four thousand soil samples from practically all sections of the state indicates that 95 per cent of the farm soils of West Virginia need lime.

Lime may be expected to give returns of four dollars or more for each dollar invested in it when used on land where needed, and in connection with good cropping and fertilizer practice. Lime and acid phosphate applied as a top dressing to pastures may be expected to yield excellent profits.

In some sections it is cheaper to buy material than to manufacture it at home; in others, roads, freight, and distance to haul make home manufacture of liming material advisable.

The community and custom pulverizers are giving satisfaction in most cases where in use.

Where only a small amount of lime is needed and there is available both limestone and fuel the lime stack is best suited to the need.

Where considerable lime is needed each year and plenty of fuel and limestone are available the permanent kiln is better suited.

Little or no difference should be expected in the returns from the use of chemically equivalent amounts of different forms of lime.

Lime does not take the place of fertilizer.

Generally the best time to apply lime is when there is time to do the work and roads and fields are in condition to haul over.

The best rate of application is generally two tons of ground limestone or its equivalent per acre for the first application and one ton per acre every six years thereafter. Such applications should be based upon the results of soil tests.

Greatest profits can be expected from the use of lime only when it is used in connection with a good crop rotation and fertilizing plan.

Bulletin 216 February, 1928

Agricultural Experiment Station
College of Agriculture, West Virginia University
N. J. Giddings, Acting Director
Morgantown

Varietal Experiments With Tobacco

A ladder for hauling tobacco without injury

By

T. C. McILVAINE and R. J. GARBER

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*Varietal Experiments With Tobacco**

The production of tobacco in West Virginia is largely confined to a section embracing eight counties in the southwestern part of the state. These counties are Cabell, Lincoln, Putnam, Mason, Wayne, Jackson, Boone, and Kanawha, of which the first three named produce approximately five million of the seven and one-half million pounds produced annually in the state.

The varieties of tobacco grown in this section belong, in the main, to the Burley type which is used primarily for the manufacture of chewing and smoking tobaccos. Inasmuch as no definite experimental evidence as to the relative values of the different varieties grown in this section was available, varietal experiments were begun in the spring of 1922, at the Lakin substation in Mason County.

EXPERIMENTAL METHODS AND SOURCES OF VARIETIES

Soil Treatment

The plots on which the varietal experiments were carried out were located on first bottom land near the Ohio River. The soil was a highly productive Huntington silt loam which had been in grass for several years previous to its use for experimental purposes. The grass sod was plowed in 1921 and planted to corn. In two of the four years in which the varietal experiments were underway, tobacco followed corn and in the other two years tobacco followed oats.

No fertilizer was applied to the tobacco or to any crop preceding it. (The cropping plan followed and the lack of a fertilizer treatment are not necessarily recommended practices. This procedure was followed in this case because of certain other experiments under way.) In the spring of 1925 a heavy cover crop of rye was turned under for tobacco.

Varieties

In Table 1 are listed the source of seed and the seventeen varieties and strains of tobacco which were tested during the four-year period,

---

*The tobacco experiments at Lakin are carried on in cooperation with the Office of Tobacco Investigations, Bureau of Plant Industry, United States Department of Agriculture. The writers are indebted to Dr. W. W. Garner, Chief of that Office, for valuable suggestions and for the photographs used in this bulletin.
Submitted for publication May, 1926.

from 1922 to 1925, inclusive. Seed of most of the varieties was obtained from the United States Department of Agriculture, Office of Tobacco Investigations. Five strains were obtained from the Kentucky Agricultural Experiment Station, and one strain from the Huntington Tobacco Warehouse.

The variety designated as W. B. U. V. is a strain of drooping leaf Burley, resistant to root-rot, which was developed at the University of Wisconsin. The five lots designated as S. B. No. 1, No. 9, No. 9a, No. 10 Ba, and No. 10 Fa, were, at the time of their introduction, third and fourth generation selections made in a cross between W. B. U. V. and Judy's Pride, a strain of Standup Burley. Beinhart is a pure line selection of the drooping type of Kentucky White Burley. The strain A. S. 7 is a selection from Vimont-Kelley and is resistant to root-rot. The history of the strain grown as Kentucky Selection is not known.

TABLE 1.—Tobacco Varieties Tested and Sources of Seed with Reaction to Root-rot and Character of Growth.

Names of Varieties or Strains	Sources of Seed	Reaction to Root-rot	Character of Growth
Kelley	Ky. Exp. Station	Non-resistant	Standup
S. B. No. 1	U. S. Dept. of Agr.	Resistant	Standup
No. 9	U. S. Dept. of Agr.	Resistant	Standup
No. 9a	U. S. Dept. of Agr.	Resistant	Standup
No. 9Ba	U. S. Dept. of Agr.	Resistant	Standup
No. 9Fa	U. S. Dept. of Agr.	Resistant	Standup
Kentucky Selection	Ky. Exp. Station	Resistant	Standup
A. S. 7	Ky. Exp. Station	Resistant	Standup
Judy's Pride	U. S. Dept. of Agr.		Standup
Pepper	Ky. Exp. Station		Standup
Beinhart Sel. 1917	U. S. Dept. of Agr.		Non-standup
W. B. U. V.	U. S. Dept. of Agr.	Resistant	Non-standup
Halley	U. S. Dept. of Agr.		Non-standup
White Twist Bud	U. S. Dept. of Agr.		Non-standup
Red	Ky. Exp. Station		Non-standup
Lockwood	U. S. Dept. of Agr.	Non-resistant	Non-standup
Lockwood	Huntington Tobacco Warehouse	Non-resistant	Non-standup

Table 1 also shows the reaction of some of the strains of tobacco to root-rot and the growth habit ("standup" or "non-standup") of all the strains in the test. The "standup" types have erect leaves, whereas the "non-standup" types have more or less drooping leaves.

Growing the Crop

The plants for the varietal experiments were produced in the usual manner. Seed was sown about the middle of March in a prepared

seed-bed at the rate of a scant teaspoonful per 100 square feet of surface. The seed was mixed with ashes to facilitate a uniform distribution in sowing. After the seed was sown the surface of the entire seed bed was tramped firmly and then covered with a good grade of tobacco muslin. It was necessary, of course, to keep the seed bed well watered. The seedlings were transplanted to the plots between June 1 and 10.

The plants were grown in rows 3½ feet apart and spaced 18 inches apart in the rows. During the first three years of the experiment each plot was made up of three rows with fourteen plants per row. Only the twelve inner plants of the middle row were harvested for the yield data. In 1925 each plot was made up of four rows of the same length as in previous years and the yield record was obtained from twenty-four plants of the two inner rows. End plants were discarded. In 1923 each variety was grown in five plots, and in 1922, 1924, and 1925 in four plots, systematically distributed over the entire experimental field. During the latter two years every third plot was used as a check.

When the tobacco on any particular plot was fully matured, the stalks were split, cut, and then spudded. Six plants were placed on a stick. In this condition, they were transported to a scaffold where they remained until well wilted and then were hung in the tobacco curing barn.

A scaffold in the field to facilitate the wilting of tobacco.

Grading

Each year the tobacco was carefully graded. The sticks of tobacco were taken to a conditioning cellar until in proper "case" for handling. A sky-light in the grading room increased the intensity and uniformity of the light.

A tobacco plant with a 16-pound manila paper bag in place to prevent cross-pollination.

When the leaves were stripped from the stalks they were divided into a maximum of sixteen different grades, dependent on quality. The principal grades recognized by the Burley Tobacco Growers Cooperative Association are: A, flyings; B, trash; C, lugs; D, bright leaf; E, red leaf; F, heavy tips; F. S., smoking tip; C. W., cigarette wrapper; and T. W., twist wrapper. Each of these grades, except the "smoking tip" and the two "wrappers," is divided into seven classes, number one being the best and number seven the poorest of a particular grade. In 1925, through the courtesy of the Huntington Branch of the Burley Tobacco Growers' Cooperative Association, it was possible to study the general relation between the grading of the varieties at the substation and the official grading of the same varieties, at Huntington. The results of this study are recorded in Table 2.

The vertical columns in Table 2, numbered from one to sixteen, contain the grades of tobacco made at the Lakin substation, and the twenty-two horizontal rows, labeled A7, A6, etc., contain the official grades of tobacco made at Huntington. Beginning at the upper left hand corner of Table 2 the official grades reading from the top down and the grades made at the substation reading from left to right are arranged in the same order. Although the official grades and the substation grades do not exactly correspond, the relative position of the grades in one system as arranged in the table corresponds with that in the other system. In general, the substation grades are somewhat more inclusive than the official grades.

TABLE 2.—Correlation Between the Official Tobacco Grades of the Burley Tobacco Growers' Cooperative Association and the Grades Established at the Lakin Substation for the Varieties of Tobacco Grown at Lakin in 1925.

Official Grades	Substation Grades 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
A7	45																45
A6	58																58
A5	2	4	3														9
A4		12		1	1												14
B7		1	1	7	14												23
B6		73	14		16		3	1									107
B5		9	1	7	49		8	17	5	1							97
B4					1		20	19	6	4	1						51
B3							5	9									14
C7		6			3			5	4	7	1	1					27
C6				1	7		6	21	36	27	17	10					125
C5							15	17	36	37	17	5					127
C4								1	4	5	1						11
D6										6	35	43	12				96
D5										7	18	13	2	1			41
E7										1		1	1	1	8		12
E6											1	1	38	8	9		57
E5											3	3	16			5	27
E4												1	22				23
F5															1	45	46
F4													1		20	50	71
F3													1		55	2	58
Total......	105	105	19	16	91		57	90	91	95	94	78	93	10	93	102	1139

Under substation Grade 1, 105 samples were found which were placed in this grade. This same tobacco at Huntington was placed mainly in official grades A7 and A6. Similarly, there were 105 samples which were placed in substation Grade 2, and this same tobacco was placed chiefly in official grade B6. It is evident from Table 2 that in general there was a fairly close agreement between the substation grades and the official grades, although considerable variation occurred in certain instances.

In 1925 the difference between the average value of the varieties per acre, based on the official grades, and that based on the substation grades, was $1.80. Prior to 1925, only the substation grades were available and it was upon the basis of these grades that yields and values were determined. In view of the correlation of grades by the two systems, the yields and values based on the substation grades may be considered as a trustworthy index of the yields and values based on the official grades.

Data Collected in 1925

As has been previously stated, the tobacco produced on each plot in 1925 was first graded and labeled, and then shipped to the Huntington Branch of the Burley Tobacco Growers' Cooperative Association where it was regarded according to official standards and then sold on the leaf tobacco market. The average yield of tobacco in pounds per acre and its value for each variety are shown by grades in Table 3.

In columns 2, 4, 6, and 8 are given the yields per acre in pounds for grades A7 and A6, A5, and A4, respectively. (These yields are recorded in round numbers only. On the other hand the values recorded in the adjacent columns were computed by multiplying the weight, carried to one decimal, by the auction price per hundred pounds, which may be found at the bottom of the table.) Of the four classes of tobacco just mentioned, A4 on the average commands the highest price on the market. Considering all the classes of the A grade (flyings) together, it is apparent that Lockwood (U. S. D. A.) and White Twist Bud each produced considerable more tobacco of this grade than did any other variety in the test. Beinhart, Judy's Pride, No. 10 Ba, No. 9a, and S. B. No. 1 each produced somewhat more than 250 pounds of A grade tobacco. The least amount of this grade of tobacco was produced by Pepper which was closely followed by A. S. 7 and No. 10 Fa.

In a similar manner, the yields of the several varieties and strains of tobacco, with respect to grades B, C, D, E, and F, might be discussed. This does not seem worth while, however, in view of the fact

that the data in Table 3 are from only one year's work. The table is published in extended form, primarily to show the different grades of tobacco produced by the several varieties in the test.

The values of the various grades at the time the 1925 crop was marketed are also shown. In general, grades A4, B7, B6, B5, B4, B3, C4, and C5 brought the highest prices per pound, whereas grades E7, F3, F4, and F5 brought the lowest. Considering the last four grades together, it may be of some interest to point out which varieties produced relatively high and which relatively low yields. Lockwood (U. S. D. A.) was the highest producer of the low grades with a total of 404 pounds, and the Huntington strain of Lockwood came second with a total of 379 pounds. The varieties No. 9, No. 10 Ba, Kentucky Selection, A. S. 7, Beinhart, and Halley ranged in production of these inferior grades from 306 to 337 pounds. Two varieties gave low yields, namely, Pepper with a total of 163 pounds and Red with a total of 167 pounds.

The ratios (expressed in percentages) of the total average yield (columns 8, 10, 12, 14, 16, 18, 20, and 22, Table 3) of the aforementioned more valuable grades, to the total average yield (column 46) of the crop for each variety in 1925, have been calculated and are given in the following list, in which the varieties are arranged in a descending order with regard to their ratios. In other words, the varieties which are named first produced the greatest relative amount of high grade tobacco. The varieties together with their percentages of good grade tobacco are as follows: Kelley, 58; Pepper, 55; No. 10 Ba, 51; Judy's Pride, 41; No. 10 Fa, 40; No. 9, 37; A. S. 7, 33; Lockwood (U. S. D. A.), 31; W. B. U. V., 30; Lockwood (Huntington), 30; Beinhart, 28; Kentucky Selection, 28; No. 9a, 26; Red, 22; S. B. No. 1, 21; Halley, 18; and White Twist Bud, 13. It is apparent that in 1925 Kelley, Pepper, and No. 10 Ba produced the highest percentages, by weight, of the better grades of tobacco.

DATA COLLECTED DURING FOUR YEARS

It has already been stated that in 1922, 1923, and 1924 the several varieties and strains of tobacco in the experiments herein reported were graded only at the Lakin substation. The tobacco on each plot was graded and the weight of each grade determined in a manner similar to that followed in 1925. Each grade was given a value based on current market prices for that particular year. In this way the data were recorded and collected in a table each year somewhat like Table 3 except that the yields and values were based on the tobacco grades made up at the substation.

TABLE 3.—Average Yield of Tobacco in Pounds Per Acre and Its Value by Grades as Determined on the Huntington Market, for Each of the Seventeen Varieties and Strains Grown at the Lakin Substation in 1925.

VARIETIES AND STRAINS	OFFICIAL TOBACCO GRADES							
	A7		A6		A5		A4	
	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Kelley	74	$17.68	110	$26.31	13	$3.03	6	$1.73
S. B. No. 1	275	66.02						
No. 9	115	27.62	11	2.74			77	20.90
No. 9a			205	49.20			50	13.37
No. 10 Ba	74	17.83	98	23.59			88	23.76
No. 10 Fa	83	19.80	91	21.86				
Kentucky Selection	98	23.59	89	21.31				
A. S. 7	69	16.61	112	26.78				
Judy's Pride	104	25.01	87	20.98			69	18.74
Pepper			118	28.34	46	10.92		
Beinhart	72	17.18	118	28.32			96	25.92
W. B. U. V.	42	9.96	156	37.49				
Halley	37	8.83	118	28.34	82	19.75		
White Twist Bud	56	13.49	209	50.06			121	32.56
Red	35	8.28	95	22.68			67	18.00
Lockwood (U. S. D. A.)	153	36.72	81	19.34			211	57.05
Lockwood (Hunt)	19	4.58	152	36.40	65	15.65		
Auction price per cwt		$24.00		$24.00		$24.00		$27.00

TABLE 3.—Continued.

VARIETIES AND STRAINS	OFFICIAL TOBACCO GRADES													
	B7		B6		B5		B4		B3		C4		C5	
	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values
(1)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
Kelley	37	$10.02	148	$39.85	170	$47.48	176	$47.63	53	$14.36	61	$16.37	452	$122.55
S. B. No. 1	34	9.26	258	69.77	132	3[illegible].07								
No. 9			158	42.69	185	51.91	71	19.20	79	15.80			92	24.79
No. 9a			224	60.53	49	13.80							200	54.05
No. 10 Ba	19	5.16	139	37.61	277	77.42	154	41.47					333	89.91
No. 10 Fa	12	3.29	236	63.75	113	51.75	103	27.68					295	79.54
Kentucky Selection			239	64.56	43	12.15							269	72.63
A. S. 7	15	3.92	309	83.43	36	9.97	93	25.16					247	66.72
Judy's Pride	18	4.86	89	24.13	275	77.20	78	20.98	25	6.77			259	69.80
Pepper	16	4.21	167	40.09	57	15.90	172	46.36	149	40.23			505	136.35
Beinhart			248	67.07	75	20.44							184	49.68
W. B. U. V.	45	12.23	186	50.17	76	21.17					142	38.42	124	33.59
Halley			188	50.81	46	12.74	31	8.24					67	18.14
White Twist Bud			125	33.83	52	14.45								
Red	55	14.72	182	49.14	19	5.24					137	36.99		
Lockwood (U. S. D. A.)			196	54.99	74	19.90	74	19.90					39	10.53
Lockwood (Hunt.)			210	56.75	92	25.70	285	76.95						
Auction price per cwt.		$27.00		$27.00		$27.00		$27.00		$27.00		$27.00		$27.00

TABLE 3.—Continued.

VARIETIES AND STRAINS	OFFICIAL TOBACCO GRADES													
	C6		C7		D5		D6		E4		E5		E6	
	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values
(1)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
Kelley	76	$19.02	2	$ .54	65	$16.84	120	$31.12	21	$4.99	80	$18.65	23	$45.60
S. B. No. 1	585	146.33			35	9.13	184	47.94	81.7	19.61	100	24.05	18	3.50
No. 9	399	99.65	40	9.25	35	9.10	188	48.85					73	14.52
No. 9 a	437	109.30			103	23.03	273	70.93	20.8	4.99	70	13.87	98	19.62
No. 10 Ba	147	36.73			127	33.10	149	38.69					77	15.40
No. 10 Fa	331	82.65					138	35.88					125	25.00
Kentucky Selection	212	52.98	97	22.26	157	40.87	214	55.54	86	20.71	28	6.67	117	23.48
A. S. 7	172	43.10	14	3.29	288	74.91	171	44.38	243	58.25				
Judy's Pride	157	39.30			192	49.92	257	40.72	39	9.34	36	8.64	19	3.88
Pepper	55	13.82			144	37.44	169	43.94	115	27.60			56	11.12
Beinhart	501	125.23					335	87.05			59	14.09	164	32.74
W. B. U. V.	230	57.50	141	32.48			249	64.69	79	18.89			193	38.52
Halley	424	105.93	113	26.08	13	3.38	51	13.18	153	36.62			214	42.84
White Twist Bud	173	46.82	325	74.75	58	15.05	257	66.72	300	72.00			275	55.06
Red	290	78.38	195	44.85	297	71.17	223	58.86					304	60.78
Lockwood (U. S. D. A.)	244	65.85	156	35.81			84	21.84	208	49.92			61	12.12
Lockwood (Hunt.)	310	77 55					240	62.43	147	35.21			38	7.62
Auction price per cwt		$25.00		$23.00		$26 00		$26 00		$24 00		$24.00		$20.00

TABLE 3.—Concluded.

VARIETIES AND STRAINS	OFFICIAL TOBACCO GRADES										
	E7		F3		F4		F5		Total		
	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds*	Values	Values Per cwt.
(1)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)
Kelley	3	$ .43	102	$16.39	91	$13.66	33	$5.02	1,917	$478.71	$24.97
S. B. N2. 1			194	31.04	37	5.58	77	11.61	2,013	480.91	23.89
No. 9			152	24.38	127	19.04	27	4.01	1,809	434.45	24.01
No. 9a			130	20.80	95	14.21	21	3.15	1,980	478.90	24.17
No. 10 Ba			202	32.37	76	11.40	29	4.32	1,989	488.76	24.57
No. 10 Fa			116	18.62	80	11.94	92	13.77	1,884	453.54	24.07
Kentucky Selection	119	19.09	84	13.41	105	15.69	29	4.37	1,988	469.31	23.63
A. S. 7	126	20.18	110	17.55	33	4.95	59	6.90	2,097	508.10	24.23
Judy's Pride			102	16.26	97	14.52	95	14.30	1,999	491.35	24.58
Pepper			51	8.22	112	16.76			1,931	486.30	25.18
Beinhart			166	26.56	61	9.15	83	12.41	2,159	515.84	23.89
W. B. U. V			50	7.92	44	6.60	130	21.52	1,887	451.15	23.90
Halley			109	17.44	139	20.85	61	9.21	1,846	422.38	22.89
White Twist Bud	137	21.86			101	15.18	57	8.52	2,245	520.35	23.20
Red	37	5.89	36	5.79	43	7.10	51	7.70	2,069	494.77	23.91
Lockwood (U. S. D. A.)	151	24.08	82	13.10	120	18.00	51	7.71	1,910	446.96	23.40
Lockwood (Hunt.)			298	47.74	49	7.29	32	4.74	1,937	458.61	23.67
Auction price per cwt		$16.00		$16.00		$15.00		$15.00			

*Total weights by varieties based on yields for each grade and recorded to one decimal, but with fractions dropped in totals.

The total average yield of tobacco in pounds per acre and the estimated total value for each variety, for each of the three years 1922, 1923, and 1924, are brought together in Table 4. In the same table are shown the total average yields and the actual values of the 1925 crop, based on the official grades, on the Huntington market.

In column 1 of Table 4 the varieties and strains of tobacco are arranged according to the values of their average annual yields, which are recorded in column 11. The average annual value for any particular variety was obtained by adding together the yearly values of that variety recorded in columns 3, 5, 7, and 9 and dividing the sum by four. The average yields in column 10 are obtained in a similar manner. The value per hundred pounds of tobacco (column 12) for any variety was computed by dividing the average value of that variety by its average yield in pounds and multiplying the quotient by 100.

Considering the varieties which were grown for four years, it is apparent from column 11 that there were four of them whose yields had an average annual value somewhat greater than $500 per acre. These varieties were White Twist Bud, Red, Pepper, and Kelley, of which, the first named variety had considerably the highest value. The three varieties with the lowest average annual value were No. 10 Fa, W. B. U. V., and No. 9.

The rank of the four varieties which gave the highest average yields (column 10) is the same as their rank with respect to average annual values. The average yield per acre of White Twist Bud (a heavy dark tobacco) was 2,264 pounds; of Red, 2,144 pounds; of Pepper, 2,043 pounds; and of Kelley, 2,016 pounds. The first two varieties gave average annual yields of more than 100 pounds in excess of the last two varieties.

With respect to average values per hundred pounds of tobacco (column 12), Kelley ($25.00) ranked first, Pepper ($24.73) second, Red ($23.66) third, and White Twist Bud ($23.55) fourth. It should be noted that the rank of these four varieties with respect to average values per hundred pounds is just the reverse of what it was with respect to average yields (column 10) and average values (column 11). The extreme difference in the average values per hundred pounds of the four varieties is $1.41.

Beinhart was grown in only three of the four years in which the experiment was under way, but in each of those three years it ranked near the top with respect to yield and value.

TABLE 4.—Summary of the Tobacco Yields and Values Per Acre for the Seventeen Varieties and Strains Grown at the Lakin Substation from 1922 to 1925, Inclusive.

VARIETIES AND STRAINS	1922†		1923†		1924†		1925†		Average		Value per cwt.
	Yields in Pounds	Values	Y'elds in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	Yields in Pounds	Values	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
White Tw'st Bud	2,236	$661	2,177	$445	2,399	$507	2,245	$520	2,264	$533	$23.55
Red	1,716	480	2,508	566	2,283	488	2,069	495	2,144	507	23.66
Pepper	2,281	633	1,970	452	1,990	450	1,931	486	2,043	505	24.73
Kelley	1,999	547	2,160	515	1,989	478	1,917	479	2,016	504	25.00
A. S. 7	1,800	506	2,192	460	1,954	406	2,097	508	2,011	470	23.37
Lockwood U. S. D. A.	2,024	519	1,974	427	2,132	446	1,910	447	2,010	460	22.88
Lockwood (Hunt)	1,996	521	1,940	433	2,046	424	1,937	459	1,980	459	23.18
Halley	2,410	645	1,793	391	1,809	375	1,846	422	1,965	458	23.32
Kentucky Selection	1,871	479	2,180	535	1,665	345	1,988	469	1,926	457	23.72
Judy's Pride	2,024	526	1,926	439	1,835	391	1,999	465	1,946	455	23.40
No. 10 Ba	2,070	583	1,716	365	1,548	345	1,989	489	1,831	446	24.33
No. 9a	2,099	541	1,690	378	1,640	350	1,980	479	1,852	437	23.60
S. B. No 1	1,879	500	1,823	385	1,679	361	2,013	481	1,849	432	23.39
No. 9	2,028	523	1,787	388	1,723	369	1,809	434	1,837	429	23.33
W. B. U. V.	1,996	495	1,793	398	1,722	357	1,887	451	1,849	425	23.00
No. 10 Fa.	1,970	448	1,734	391	1,767	399	1,884	454	1,839	423	23.00
Beinhart	2,614	724			2,234	474	2,159	516	2,336*	571*	24.44*

*Average of only three years.

†Values for 1922, 1923, and 1924 are estimated; 1925 values are actual.

CONCLUSION

Under the conditions of the tobacco varietal experiments described in this bulletin, the varieties White Twist Bud, Red, Pepper, and Kelley had the greatest average values per acre for the four years the experiment was under way. Kelley and Pepper were somewhat superior in quality to White Twist Bud and Red.

On the basis of only three years' work, Beinhart gives promise of being a high yielder for the locality in which it was tested.

Bulletin 217 March, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director

Morgantown

A Study of Correlated Inheritance in a Certain Avena Cross

By

R. J. GARBER and K. S. QUISENBERRY

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D.......President of the University
N. J. GIDDINGS, Ph. D.......Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr.......Agricultural Editor
JOHN C. JOHNSTON.......Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick. Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

TABLE OF CONTENTS

*A Study of Correlated Inheritance in a Certain Avena Cross**

The inheritance of quantitative characters is of particular interest to the plant breeder engaged in an attempt to produce superior economic plants. More detailed information concerning the manner of transmission of size characters in our common crop plants is needed to aid in accomplishing crop improvement. It was with the hope of contributing something to our present knowledge that a number of size inheritance studies in oats were planned a few years ago. The results of two of these studies have been published in recent bulletins of this station.† A review of the literature pertaining to the inheritance of quantitative characters in oats may be found in these bulletins and also in a recent publication of the Pennsylvania Agricultural Experiment Station.‡

The parent plants, a few F_1 plants, and a considerable number of the F_2 and the F_3 generations of *Avena sativa* used for this study were grown in the plant breeding nursery at Morgantown in 1923. The cross was first made in 1921 for the purpose of studying the inheritance of resistance to smut and continued as such for three years, but the smut epidemic failed to materialize, and since the parents of the cross differed with respect to a number of characters, it was decided to use the material for an inheritance study of these characters.

MATERIAL AND METHODS

The parents of the progeny, whose breeding behavior is described in the following pages, were single panicle selections made from the varieties Black Mesdag and Gopher. Black Mesdag is a midseason oat, highly resistant to oat smut, with black seed and stiff culms. It has somewhat broader leaves than Gopher and is inclined to develop fewer clums per plant.

Gopher, a pure line selection made at the Minnesota Agricultural Experiment Station from the variety "Sixty Day," is an early-maturing, white-seeded strain with an exceptionally stiff straw. It has a somewhat coarser appearance than Sixty Day, and also has

---

*Submitted for publication May, 1926.

†QUISENBERRY, K. S. Correlated Inheritance of Quantitative and Qualitative Characters in Oats. W. Va. Agr. Exp. Sta. Bul. 202. 1925.

†ODLAND, T. E. The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Orientalis. W. Va. Agr. Exp. Sta. Bul. 219, April, 1928.

‡NOLL, C. F. Studies of Inheritance of Earliness in Certain Avena Crosses. Pa. Agr. Exp. Sta. Bul. 194. 1925.

greater awn development under the environmental conditions at Morgantown. It is one of the highest yielding varieties of oats that have been grown on the Agronomy Farm at Morgantown.

These varieties were crossed in the greenhouse, and in 1921, a small F_1 generation was grown. An F_2 generation was grown in 1922 but no notes were taken on the characters discussed in this bulletin until 1923, when a considerable number of F_2 and F_3 families was available. In addition, a few F_1 plants and the parents, all grown under similar conditions, were also available during this year.

Just previous to the planting of this material, the seed was treated with smut, but, owing apparently to the adverse conditions for the development of the fungus, very few plants of the susceptible parent became infected. In view of this fact it was decided to use the plants for a study of the inheritance of leaf width, number of culms, date of heading, and color of seed in their relation to one another. The study was continued in 1924 when the seed was not treated with smut and somewhat larger F_3 families were grown.

In 1923 the parents and the progeny were grown in rows eight feet long and one foot apart, with 35 seeds spaced approximately three inches apart in each row. It was necessary to fill out some rows with bulk seed, the plants from which were discarded later. The plants growing next to the borders were not considered, owing to the obvious border influence on development. In 1924 the material was grown in rows five feet long and one foot apart, the 25 seeds planted per row being spaced at approximately equal distances. Two individually spaced seeds of the Gopher parent were planted at each end of the rows to prevent border influence on the experimental plants, but were pulled and discarded just previous to heading. The parents were grown every twelfth row among the F_3 families in 1923 and in 1924. The parents were also grown with the F_2 generations. In 1923 the parents and F_3 families were grown in single-row plots but in 1924 they were grown in two-row plots.

Practically all the notes were taken in the field. Heading notes were taken every other day and a plant was considered headed when all the spikelets had emerged from the boot on the main culm. Leaf widths were determined by measuring in millimeters the width of the second leaf (from the top down) at the widest part, which is relatively near the juncture of the blade with the sheath. The measurements were taken after the plants were headed, but before the leaves became dry. The number of culms and color of the seed were ascertained at harvest after the plants had matured. Individual plant data

were taken on part of the parents and on the F_1 and F_2 generations grown in 1923 and on all the material grown in 1924. Number of culms and leaf widths were obtained on the F_3 families grown in 1923, but no attempt was made to keep the notes of individual plants separate.

The soil on which the plants were grown was a DeKalb silt loam of medium productivity. It will be shown later that the plot series used in these experiments were not as uniform as was desirable.

INHERITANCE OF DATE OF HEADING

Preliminary Observations

In order to obtain some idea of the number of F_2 plants grown in 1924 necessary to constitute a random sample, the variability of the two F_2 families with respect to date of heading was studied. One of these families had 308 individuals and the other had 314. It so happened that one family was grown on an inferior plot and consequently the mean date of heading of the plants on this plot was different from the mean date of heading of the F_2 family on the other plot. For this reason the data from the two families were kept separate.

In Table 1 are shown the frequency distributions of the mean date of heading based on different random samples taken from the F_2 generation. It will be noted that on the average the 16-Family headed somewhat earlier than the 17-Family. In both families, it may be seen that 62 individuals chosen at random constituted a fairly trustworthy sample from which to calculate a mean. In the case of the 17-Family, 30 individuals taken at random gave a fairly trustworthy sample. The mean dates of heading of the ten samples, each made up of 30 individuals, fall into two classes.

TABLE I.—Frequency Distributions for the Mean Dates of Heading Based on Different Samples Taken from the F_2 Generation of Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Kind of Sample	n	Mean Dates of Heading*						
		7.25	7.75	8.25	8.75	9.25	9.75	10.25
Total population, 16-Family			1					
Every 5th individual	62		4	1				
Every 10th individual	30	2	1	5	2			
Every 15th individual	20	4	4	4	3			
Total population, 17-Family						1		
Every 5th individual	62					4	1	
Every 10th individual	30					5	5	
Every 15th individual	20			1	1	4	7	2

*The date of heading of the first F_2, plant was considered as 1, and the mean dates given here are in terms of days.

TABLE 2.—Frequency Distributions for the Standard Deviations of Dates of Heading Based on Different Samples Taken From the F_2 Generation of Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Kind of Sample	n	* Standard Deviation of Date of Heading					
		1.5	1.8	2.1	2.4	2.7	3.0
Every 5th individual	62		3	5	2		
Every 10th individual	30	1	7	5	5	2	
Every 15th individual	20	3	10	8	6	1	2

The frequency distributions of the standard deviations based on the same random samples as previously discussed are shown in Table 2. Since no appreciable difference was discerned between the distributions from the two families, they were combined in the table. The range of the standard deviations of date of heading of the ten random samples, each made up of 62 individuals, was from 1.8 to 2.4, inclusive. It is apparent from Table 2 that 20 or 30 individuals were not enough to constitute a very trustworthy sample from which to calculate a standard deviation.

There were approximately forty individuals in each F_3 family grown in 1924.

Environmental Influence

Before taking up the discussion of the inheritance of date of heading it may be well to point out the possible non-genetic influence on the development of this character. In 1924 the correlation between the mean date of heading of consecutive plots of the parents growing with the F_3 families was determined and also the correlation between the means of the date of heading of the two different parents growing in adjacent plots. If a marked influence of soil on date of heading existed, the correlation coefficients should show it. The correlation between mean date of heading and number of plants per plot was also determined for each parental plot. The data are presented in Table 3.

TABLE 3.—Correlation Coefficients That Show the Effect of Environment on Date of Heading in the Oat Parents Grown in 1924.

Nature of Correlation	n	r
Between mean dates of heading in consecutive plots of Gopher	27	+0.372±0.112
Between mean dates of heading in consecutive plots of Black Mesdag	27	+0.429±0.106
Between mean dates of heading of Gopher and of Black Mesdag in adjacent plots	31	+0.712±0.060
Between mean dates of heading and number of plants per plot of Gopher	31	−0.679±0.065
Between mean dates of heading and number of plants per plot of Black Mesdag	31	−0.0[illegible]0±0.120

The correlation coefficient between the mean dates of heading in consecutive plots of Gopher is $+0.372 \pm 0.112$, and in consecutive plots of Black Mesdag $+0.429 \pm 0.106$. These facts and the relatively high correlation ($+0.712 \pm 0.060$) obtained between the mean dates of heading of the two parents growing in adjacent plots indicate that the soil medium in which the plants grew had a rather marked influence on date of heading.

The number of plants per plot in the Gopher parent was negatively correlated (-0.679 ± 0.065) with the date of heading but in the Black Mesdag parent no such relationship was found. In this case correlation (-0.090 ± 0.120) was sensibly zero.

In addition to the environmental factors already mentioned, season and time of planting may influence the date of heading. In 1923 the difference between the mean dates of heading for the two parents was about two weeks, whereas in 1924 the difference was approximately one week.

Data In 1923

Individual plant notes were taken on the F_1 and F_2 plants in 1923 only. The mean date of heading of each parental plot was estimated. The approximate mean date of heading of each of the two plots of Gopher growing with the first and second generation plants was June 18 and for each of the two plots of Black Mesdag July 1, an estimated difference between the parents of 13 days. There was no difference between the date of heading of the two F_1 plants of Gopher $\times$ Black Mesdag and the four F_1 plants of the reciprocal cross. The mean date of heading of the six F_1 plants was June 16 or approximately the same as the early maturing parent. This is in agreement with the behavior of some of the F_1 generations reported by Noll.*

The F_2 generation showed considerable variability with respect to date of heading as was expected. The frequency distribution is shown in Table 4. The range of date of heading is from the early parent to

TABLE 4.—Frequency Distribution of the Dates of Heading for the F_2 Generation of Gopher $\times$ Black Mesdag and the Reciprocal Grown in 1923.

Name of Strain	Dates of Heading†										
	6/16	6/18	6/20	6/22	6/24	6/26	6/28	6/30	7/2	7/4	n
Gopher X Black Mesdag & Reciprocal.	60	58	29	44	59	116	67	21	0	1	455

†Given as month and day; thus 6/16 means June 16.

*See footnote on page 5.

the late parent and shows clearly that segregation has occurred. It is apparent, too, that there were more F_2 plants with a date of heading similar to that of the early parent (June 18) than there were to that of the late parent (July 1).

Data In 1924

Notes were taken on each individual plant for all the material grown in 1924. The difference between the average date of heading for the two parents was approximately one-half of what it was in 1923 owing, undoubtedly, to environmental influence. The frequency distributions of the F_2 generation and the parents which were grown with it are shown in Table 5. There were 308 F_2 plants of Gopher $\times$ Black Mesdag and 314 F_2 plants of the reciprocal cross. The difference between the mean dates of heading of the two F_2 families was 1.51 ± 0.11, which is significant in the light of its probable error. One of the F_2 families, unfortunately, was planted on an inferior plot which fact probably accounts for the difference obtained.

It is evident from Table 5 that segregation for date of heading occurred in the F_2 generation. The mode of the F_2 generation considering both families together corresponds to the mode of the Gopher parent. The F_2 distributions clearly indicate that earliness is inherited as a dominant character. In 1924 the two parents overlapped somewhat in date of heading. The variability of the late parent, as indicated by the standard deviation, is practically the same as that of the earlier parent. The means for dates of heading of the F_2 families are much nearer to the mean of the Gopher parent than to the mean of the Black Mesdag parent.

That date of heading is a definitely inherited character may be further shown by correlating the date of heading of individual F_2 plants with the mean date of heading of their F_3 progeny. This has been done in Table 6. The correlation coefficient obtained was $+0.401 \pm 0.046$, which indicates that there was a tendency for F_2 plants to transmit date of heading to their respective F_3 families.

The frequency distributions of the mean dates of heading of the F_3 families and the parents grown with them are shown in Table 7.

The mean date of heading of each of five of the F_3 families was earlier than the mean date of heading of the earliest plot of Gopher. On the other hand there were four plots of Black Mesdag with mean dates of heading later than the mean date of heading of the latest F_3

TABLE 5.—Frequency Distributions of the Dates of Heading for the Parents, the F_2 Generation of Gopher × Black Mesdag, and the Reciprocal Grown in 1924.

Names of Strains	Dates of Heading*																n	m	σ
	6/28	6/29	6/30	7/1	7/2	7/3	7/4	7/5	7/6	7/7	7/8	7/9	7/10	7/11	7/12	7/13			
Gopher................			12	27	12	53	8	4	5	1							122	2.45±0.09	1.50±0.06
Black Mesdag..........										6	22	23	47	0	13	1	112	9.50±0.08	1.33±0.06
Gopher x Bl. Mes.......	7	10	20	46	25	95	52	6	35	0	9	0	3				308	2.94±0.08	2.20±0.08
Bl. Mes. x Gopher.......		3	6	18	19	58	87	15	63	7	31	0	5	2			314	4.45±0.08	2.19±0.06

*Given as month and day; thus 6/28 means June 28.

TABLE 6.—Correlation Between Date of Heading of Individual Plants in F_2 and the Mean Date of Heading of Their F_3 Progeny in the Cross Gopher × Black Mesdag and the Reciprocal.

Date of Heading in F_2	Mean Dates of Heading in F_3											Total
	5	6	7	8	9	10	11	12	13	14	15	
15–16	1		3	10	4		1					19
17–18		1	4	5	4	2	2	1				19
19–20	1	1	1	1	3	1	1			1		10
21–22		1	4	3	1	3	2	1	1			16
23–24	1		4	5	3	3		4	2			22
25–26		1	5	5	7	7	7	6	2			40
27–28			1	2	1	5	2	3	2	1	2	19
29–30				1			1	1		1		4
1–2												0
3–4							1					1
Total..................	3	4	22	32	23	21	17	16	7	3	2	150

$r = +0.401 \pm 0.046$

TABLE 7.—The Mean Dates of Heading for the F_3 Families and the Parents of the Cross Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Names of Strains	Mean Dates of Heading*														n
	6/29	6/30	7/1	7/2	7/3	7/4	7/5	7/6	7/7	7/8	7/9	7/10	7/11	7/12	
Gopher.............................			9	15	5	2									31
Black Mesdag.........................									1	5	17	4	3	1	31
F_3 Families	1	4	10	33	24	22	19	18	12	4	2	1			150

*Given as month and day; thus 6/29 means June 29.

family. As in the F_2 generation, the mode of the mean dates of heading of the F_3 families corresponds with the mode of the mean dates of heading of the Gopher parent.

In connection with analyzing the F_3 data it is necessary to know not only the mean date of heading of each F_3 family and of each plot containing the parents, but also something of their relative variability. To obtain such a measure the means and the standard deviations of both the means and standard deviations of each parental plot, with respect to date of heading were calculated. The results are recorded in Table 8.

One would expect about 95.5 percent of the variates of a normal frequency distribution to fall within the range delimited by the mean plus or minus two times the standard deviation ($m \pm 2\sigma$). If such a

TABLE 8.—The Means and Standard Deviations of Both the Means and Standard Deviations for Dates of Heading of Each Group of Plots Containing the Parents Grown with the F_3 Progeny in 1924.

Names of Strains	Number of Plots	M of Means	σ of Means	M of S. Devs.	σ of S. Devs.
Gopher	31	7 4323	0 8232	1.2726	0 1963
Black Mesdag	31	14.6694	0.9341	1.3855	0.2444

limit is defined from the data in Table 8 we find that for the Gopher parent the limits of the means are $7.4323 \pm 2 \times 0.8232$ or 5.7859 and 9.0787 and for the Black Mesdag parent the limits are $14.6694 \pm 2 \times 0.9341$ or 12.8012 and 16.5376. In a similar manner the limits of the standard deviations for the Gopher parent are 0.8800 and 1.6652 and for the Black Mesdag parent they are 0.8967 and 1.8743.

In Table 9 the F_3 families are classified according to the foregoing defined limits. While this classification is somewhat arbitrary, it does afford a method of comparing the F_3 families with the parents in regard to the character under discussion.

TABLE 9.—The Frequency Distributions of the Means and Standard Deviations of Dates of Heading for the F_3 Families.

Statistical Constants and Progeny	Limits							Total
(1)	(2)	(3) Gopher	(4)	(5)	(6)	(7) Bl. Mes.	(8)	(9)
Means	<	5.7859 9.0787	=	<	<	12.8012 16.5376	=	
S. Deviations	=	0.8800 1.6652	<	=	<	0.8967 1.8743	<	
F_3 Families	4	49	21	27	40	6	3	150

In column 2 are placed the four F_3 families whose means are less than the lower limit of the means for the Gopher parent but whose standard deviations fall within the limits of the standard deviation for the Gopher parent. Similarly, in column 4, there are 21 F_3 families whose means fall within the limits marked by the Gopher parent but whose standard deviations are greater than those of the Gopher parent and in most cases also greater than those of the Black Mesdag parent. The 27 F_3 families in column 5 had mean dates of heading

intermediate between the upper limit marked by the Gopher parent and the lower limit marked by the Black Mesdag parent. The standard deviations of these F_3 families fell within the limits marked by the Gopher parent. In column 6 are placed the 40 F_3 families whose means were intermediate between the upper and lower limits indicated by the Gopher and Black Mesdag parents respectively, and whose standard deviations were greater than those of the plots of Gopher, and in most cases also greater than those of the plots of Black Mesdag. The three F_3 families placed in column 8 had mean dates of heading similar to Black Mesdag but their standard deviations were somewhat greater.

From Table 9 it is apparent that there were six of the 150 F_3 families whose dates of heading were similar to that of the Black Mesdag parent. Both the means and the standard deviations of dates of heading of these six F_3 families fall within the limits indicated by the Black Mesdag parent. If to these are added the three F_3 families whose mean dates of heading were similar to, but whose variability was somewhat greater than that of the plots of Black Mesdag, we obtain 9 F_3 families breeding like the later parent. On a two factor hypothesis, one would expect about this number of F_3 families to breed like the Black Mesdag parent with respect to date of heading. To determine more precisely the breeding nature of this character would require a further study in subsequent generations.

INHERITANCE OF LEAF WIDTH

Preliminary Observations

Before deciding which leaf of the plants to measure for leaf width some preliminary studies were made. In 1923 the first, second, and third leaves (calling the uppermost leaf the first, etc.) of 359 plants of Gopher, 354 plants of Black Mesdag, and all of the F_2 plants were measured for width. The statistical constants of the various measurements made on the parents are shown in Table 10.

There was little absolute difference between the means of the widths of the first and second leaves of Black Mesdag. In the Gopher parent, however, the second leaf was approximately one-third wider than the first leaf. The third leaves of both parents were somewhat narrower on the average than their respective second leaves. The standard deviations of leaf widths of the Black Mesdag parent were somewhat greater than those of the Gopher parent. The variability of leaf widths of the first leaf in both parents was high, as indicated by the coefficients of variability. The coefficients also show that there was not much difference between the variability of the second and third leaves of the two parents.

TABLE 10.—Means, Standard Deviations, and Coefficients of Variability for Leaf Widths of the First, Second, and Third Leaves of Gopher and Black Mesdag Oats Grown in 1923.

Names of Strains	n	m			σ			c		
		First Leaf	Second Leaf	Third Leaf	First Leaf	Second Leaf	Third Leaf	First Leaf	Second Leaf	Third Leaf
Gopher P_1	359	10.65 ± 0.06	13.86 ± 0.06	11.73 ± 0.05	1.62 ± 0.04	1.74 ± 0.04	1.54 ± 0.04	15.21 ± 0.39	12.52 ± 0.32	13.16 ± 0.34
Black Mesdag P_1	354	21.67 ± 0.13	21.16 ± 0.11	16.94 ± 0.07	3.53 ± 0.0	2.94 ± 0.07	1.93 ± 0.05	16.28 ± 0.42	13.92 ± 0.36	11.41 ± 0.29

Some interesting relations between leaf widths of the first, second, and third leaves of the parents and of the F_2 generation are shown in Table 11. The highest correlations were found between the widths of the second and third leaves, the next highest between the widths of the first and second leaves, and the lowest correlations between the first and third leaves.

The correlation coefficient between the widths of the first and third leaves of the Gopher parent is 0.24±0.03, of the Black Mesdag parent 0.65±0.02, of the F_2 generation of Gopher × Black Mesdag 0.55±0.03, and of the F_2 generation of Black Mesdag × Gopher 0.48±0.04, whereas the coefficients between the widths of the second and third leaves are 0.74±0.02, 0.89±0.01, 0.79±0.01, and

TABLE 11.—The Correlation Between Certain Characters of the Parents and of the F_2 Generation of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Nature of Correlation	n	r
Gopher P_1	Between width of first and second leaves	359	0.62±0.02
Black Mesdag P_1	Between width of first and second leaves	354	0.85±0.01
Gopher x Bl. Mes. F_2	Between width of first and second leaves	323	0.70±0.02
Bl. Mes. x Gopher F_2	Between width of first and second leaves	132	0.62±0.04
Gopher P_1	Between width of first and third leaves	359	0.24±.0.03
Black Mesdag P_1	Between width of first and third leaves	354	0.65±0.02
Gopher x Bl. Mes. F_2	Between width of first and third leaves	323	0.55±0.03
Bl. Mes. x Gopher F_2	Between width of first and third leaves	132	0.48±0.04
Gopher P_1	Between width of second and third leaves	359	0 74±0.02
Black Mesdag P_1	Between width of second and third leaves	354	0.89±0.01
Gopher x Bl. Mes. F_2	Between width of second and third leaves	323	0.79±0.01
Bl. Mes. x Gopher F_2	Between width of second and third leaves	132	0.78±0.02

0.78 ± 0.02, respectively. It is of interest to note that with respect to any two leaf widths there is in no case a significant difference between the coefficients of the F_2 generations of reciprocal crosses.

In view of the fact that the widths of the first leaves of the plants were more variable than the widths of the second and third leaves, it was decided not to use the first leaf in the inheritance study. The second leaf rather than the third was finally chosen for this investigation as the third leaf dried somewhat earlier and therefore was less favorable for measurement in the field.

In connection with a study of the inheritance of a size character such as this, the question of number of plants to grow in each F_3 family usually presents itself. In order to obtain some information on this question for the particular problem at hand, the 323 F_2 plants grown in 1923 were studied. The problem was to determine the number of F_2 plants necessary to constitute a random sample of the total population. This was done by taking at random every fifth individual of the 323 F_2 leaf widths and throwing them into a frequency distribution, thus five frequency distributions, each made up of 65 individuals, were obtained. In a similar manner frequency distributions were made up by taking at random every tenth, fifteenth, and twentieth individual of the 323 F_2 leaf widths.

The means and standard deviations for all four of these frequency distributions were calculated. The distributions of the means and standard deviations are shown in Tables 12 and 13, respectively. It is obvious from these tables that at least 65 individuals should be used in order to constitute a random sample that would give a trustworthy index as to the breeding behavior of leaf width in the F_2 generation. Since in the F_2 generation maximum variability is obtained, it naturally follows that each F_3 family should be represented by the minimum number of individuals that constitutes a random sample. This

TABLE 12.—Frequency Distributions of the Mean Leaf Widths Based on Different Samples Taken From the F_2 Generation of Gopher × Black Mesdag Grown in 1923.

Kind of Sample		Mean Leaf Widths in Millimeters												
	n	14.5	14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9
Total population	323							1						
Every 5th individual	65				1		1	1	1	1				
Every 10th individual	33	1					3	2	2	1		1		
Every 15th individual	22	1				1	3	2		1	1			1
Every 20th individual	17		1			2	2		2	2	1			

TABLE 13.—**Frequency Distributions of the Standard Deviations of Leaf Widths Based on Different Samples Taken From the F_2 Generation of Gopher × Black Mesdag Grown in 1923.**

Kind of Sample	n	Standard Deviations of Leaf Widths																	
		1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4
Total population......	323										1								
Every 5th individual.......	65								2	1	1	1							
Every 10th individual.......	33				1		1		3		2		2		1				
Every 15th individual.......	22	1			1	1	2		1	1	1		1						1
Every 20th individual.......	17					2	2			2		1	2	1					

analysis of the F_2 generation grown in 1923 indicates that the F_3 families grown in 1924 were not large enough. This fact will be shown also in connection with the discussion of the inheritance of leaf width.

Environmental Influence

As in the case of date of heading, leaf width may be influenced by environment and so in 1924 a study was made of the possible effect of soil and of number of plants per row on the development of leaf width. The correlation coefficients between the means of leaf widths of consecutive plots of the parents growing with the F_3 progenies were computed as was also the correlation between the means of the leaf widths of the two parents growing in adjacent plots. The influence of number of plants per plot on mean leaf widths in each of the parents was also studied. The data are presented in Table 14.

TABLE 14.—**Correlation Coefficients That Show the Effect of Environment on the Development of Leaf Width in the Oat Parents Grown in 1924.**

Nature of Correlation	n	r
Between mean leaf widths in consecutive plots of Gopher................................	27	-0.029 ± 0.130
Between mean leaf widths in consecutive plots of Black Mesdag..........................	27	$+0.262 \pm 0.121$
Between mean leaf widths of Gopher and of Black Mesdag in adjoining plots...............	31	$+0.490 \pm 0.092$
Between mean leaf widths and number of plants per plot of Gopher.......................	31	$+0.039 \pm 0.121$
Between mean leaf widths and number of plants per plot of Black Mesdag.................	31	$+0.199 \pm 0.116$

The correlation coefficients show that in no case, except between mean leaf widths of Gopher and Black Mesdag grown in adjacent plots, was there a significant correlation. The correlation between the mean leaf widths of the adjacent parental plots was $+0.490 \pm 0.092$

which shows that there was a "place effect" in the development of this character and that the leaf widths of the two parents tended to vary in the same direction. The lack of correlation between the leaf widths of consecutive plots of either parent is probably an indication that the parental plots as checks should have been distributed more frequently throughout the series. The number of plants per plot apparently did not influence the development of the mean leaf widths in either of the parents.

Data in 1923

The leaf width of individual plants of the F_1, F_2, and F_3 generations as well as that of the parents was determined in 1923. This character proved to be highly variable and for this reason larger families should have been grown.

The distributions of the leaf widths of the F_1 and F_2 generations, together with those of the parents, all grown in close proximity, are shown in Table 15.

The data in Table 15 show that the parents differed considerably with respect to leaf width. The mean leaf width of the six F_1 plants was intermediate between the parents but it was somewhat nearer to the mean leaf width of Black Mesdag than to that of Gopher. The F_2 distribution had a lower range than the Gopher parent but did not reach the upper range of Black Mesdag. The mean leaf width of the F_2 generation was somewhat nearer to the mean leaf width of Gopher than it was to that of Black Mesdag. The standard deviation of leaf width of the Black Mesdag parent was almost as great as that of the F_2 generation; the relative variability of the latter, however, was somewhat greater.

The data for the F_3 families together with those for the parents that were grown with them are shown in Table 16. This table shows the distribution of the mean leaf width of each F_3 family and, for comparison, the distributions of the mean leaf widths of the parental plots. It is obvious from the table that the parental plots differed considerably with respect to mean leaf width and that the parental types were recovered in F_3. There were four F_3 families with mean leaf widths slightly below the plot of Gopher with the lowest mean leaf width. On the other hand the six F_3 families with the highest mean leaf widths were considerably below the plots of Black Mesdag with the higher mean leaf widths. There were only seven of the 139 F_3 families within the range of the mean leaf widths of the plots of Black Mesdag.

TABLE 15.—The Frequency Distributions of Leaf Widths for Individual Plants of the F_1, F_2, and the Parents of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Leaf Widths in Millimeters																				n	m	σ
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
Gopher			2	11	13	8	12	1	2												49	13.57 ± 0.14	1.43 ± 0.10
Black Mesdag									2	3	6	8	9	6	4	5	3	2	0	1	49	21.43 ± 0.24	2.46 ± 0.17
F_1 Family									2	1	3										6	18.17	
F_2 Family	1	6	6	31	40	59	78	63	59	40	44	14	9	3	1	1					455	15.77 ± 0.08	2.50 ± 0.06

TABLE 16.—Frequency Distributions of the Mean Leaf Widths for the Parents and F_3 Progenies of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Mean Leaf Widths in Millimeters																							n
	11.75	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75	18.25	18.75	19.25	19.75	20.25	20.75	21.25	21.75	22.25	22.75	
Gopher P_1			1	5	3	4	2																	15
Black Mesdag P_1																1	1	4	0	4	2	1	2	15
F_3 Families	1	3	1	4	13	9	13	25	20	13	11	8	6	5	0	1	6							139

It has been previously mentioned that leaf width was a variable character. This was brought out in the 1923 data when an attempt was made to show the relative variability of the parental plots as compared with the several F_3 families. The coefficients of variability were calculated for this purpose. The distributions of the coefficients for the parental plots and the F_3 families are shown in Table 17. It is evident that the range of variability for the Black Mesdag parent is almost as great as that for the F_3 families. In view of this situation it was not thought worth while to analyze the data further for relative variability.

Data in 1924

The leaf widths of individual plants of the parents and the F_2 and F_3 generations were determined in 1924. The frequency distributions of the F_2 generation and the parents which were grown with it are shown in Table 18.

In 1924 the mean leaf width of the F_2 generation was intermediate between the means of the leaf widths of the parents. The variability of leaf width of the Black Mesdag parent as measured by the standard deviation was almost as great as that of the F_2 generation. The distributions of leaf widths of the two parents as given in Table 18 are skewed to the left, or toward the narrower leaf widths.

If leaf width is an inherited character, a positive correlation should be obtained between the leaf widths of individual F_2 plants and the mean leaf widths of their respective F_3 progenies. Such a correlation is shown in Table 19. The magnitude of the correlation coefficient ($+0.512 \pm 0.041$) shows that leaf width was definitely transmitted from the F_2 to the F_3 progeny.

In Table 20 are recorded the frequency distributions of the mean leaf width of each F_3 family and for comparison the mean leaf width of each parental plot.

The mean leaf widths of the two parents do not overlap, as shown by the distribution given in Table 20, although the upper limit of Gopher reaches to the lower limit of Black Mesdag. The distribution of the mean leaf widths of the F_3 families simulates somewhat a normal frequency distribution with a range extending approximately over the combined ranges of the two parents. One F_3 family, namely 16-6-8, had a mean leaf width of only 11.82 ± 0.28 millimeters with a standard deviation of 2.40 ± 0.20 (see Table 33 of appendix). This mean was significantly lower than the lowest mean leaf width of any other F_3 family or any plot of the Gopher parent.

TABLE 17.—Frequency Distributions of the Coefficients of Variability of Leaf Widths for the Parents and F_3 Progenies of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Coefficients of Variability																		
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	n
Gopher P_1	1	0	2	3	2	4	1	1	0	1									15
Black Mesdag P_1	1	0	0	1	2	2	2	3	0	1	1	1	0	0	1				15
Gopher x Bl. Mes. F_3 and the Reciprocal		1	2	12	10	15	27	17	16	11	6	9	4	3	3	2	0	1	139

TABLE 18. The Frequency Distributions of Leaf Widths for Individual Plants of the F_2 and the Parents of Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Names of Strains	Leaf Widths in Millimeters																						n	m	σ
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
Gopher	1	3	1	1	2	4	13	22	26	26	7	11	5										122	16.88±0.14	2.30±0.10
Black Mesdag		1	0	0	0	1	0	6	2	2	3	8	7	10	12	13	20	13	11	3			112	23.04±0.22	3.39±0.15
F_2 Family	1	6	10	9	8	10	19	39	48	55	66	80	61	77	49	36	25	16	5		1	1	622	19.78±0.09	3.51±0.07

TABLE 19.—Correlation Between Leaf Width of Individual Plants in F_2 and the Mean Leaf Width of Their F_3 Progeny of the Cross Gopher × Black Mesdag and the Reciprocal.

Leaf Widths in F_2	Mean Leaf Widths in F_3												Total
	12	13	14	15	16	17	18	19	20	21	22	23	
9–10				2									2
11–12					2	3	4		2				11
13–14				4	7	8	8	4		1			32
15–16	1				1	15	14	5	3	3	1		43
17–18					1	5	9	5	9	4	1	2	36
19–20					1	1	1	6	5	5			19
21–22							1		1	1	2		5
23-24								1					1
25–26													0
27–28										1			1
29–30													0
Total..............	1	0	0	6	12	32	37	21	20	15	4	2	150

$r = +0.512 \pm 0.041$

TABLE 20.—Frequency Distributions of the Mean Leaf Widths for the Parents and F_3 Progenies of Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Names of Strains	Mean Leaf Widths in Millimeters													n
	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	
Gopher....................................					7	17	6	1						31
Black Mesdag..............................									3	4	12	9	3	31
F_3 Families..............................	1				13	19	37	30	16	18	11	5		150

In order to determine the variability of the means and the standard deviations of the parental plots with respect to leaf widths certain calculations were made. For this purpose the mean and standard deviation of the mean leaf widths of each of the two groups of parental plots were determined, and in a similar manner the mean and standard deviation of the standard deviations of each of the two groups of parental plots were computed. The constants obtained are recorded in Table 21.

In a normal frequency distribution 95.5 percent of the variates fall within the range delimited by the mean plus or minus two times the standard deviation. Theoretically, then, we would expect about 95.5 percent of the mean leaf widths of the Gopher plots to fall within the limits of $16.4855 \pm 2 \times 0.7342$ or between 15.0171 and 17.9539.

TABLE 21.—The Means and Standard Deviations of Both the Means and Standard Deviations of Leaf Widths for Each of the Two Groups of Plots Containing the Parents Grown With the F_3 Progeny in 1924.

Names of Strains	Number Plots	M of Means	σ of Means	M of S. Devs.	σ of S. Devs.
Gopher	31	16.4855	0.7342	2.0318	0.3997
Black Mesdag	31	21.5984	1.0141	2.8939	0.4696

The limits of these same Gopher plots with respect to standard deviations of leaf widths were between 1.2324 and 2.8312. Likewise the limits of the Black Mesdag plots were between 19.5702 and 23.6266 for the means of leaf widths, and between 1.9547 and 3.8331 for the standard deviations of leaf widths.

It is now possible to classify according to the foregoing defined limits the mean and standard deviation of leaf widths of each F_3 family. This has been done in Table 22.

TABLE 22.—The Frequency Distributions of Means and Standard Deviations of Leaf Widths for the F_3 Progenies.

Statistical Constants and Progeny	Limits							Total
(1)	(2)	(3) Gopher	(4)	(5)	(6)	(7) Bl. Mes.	(8)	(9)
Means	<	15.0171 17.9539	<	=	<	19.5702 23.6266	=	
S. Deviations	=	1.2324 2.8312	=	<	<	1.9547 3.8331	<	
F_3 Family	1	59	27	11	13	37	2	150

In column 2 of Table 22 is placed one F_3 family which had a lower mean leaf width than any Gopher plot and whose standard deviation fell within the limits marked by the Gopher parent. This family has already been discussed. There were 59 F_3 families (column 3) which bred similar to the Gopher parent with respect to both means and standard deviations of leaf widths. In column 4 are placed 27 F_3 families whose standard deviations of leaf widths fell within the limits marked by the Gopher parent but whose mean leaf widths were between the upper and lower limits of the Gopher and Black Mesdag parents, respectively. Eleven F_3 families had mean leaf widths which

fell within the limits indicated by the Gopher parent but their standard deviations were greater than that of the Gopher parent and in some cases greater than that of the Black Mesdag parent. The 13 F_3 families with mean leaf widths between the upper limit of the Gopher parent and the lower limit of the other parent are recorded in column 6. The standard deviations of leaf width of these families were outside the limits of the Gopher parent and in some cases also outside the limits of the Black Mesdag parents. There were 37 F_3 families which bred in a manner similar to that of the Black Mesdag parent with respect to means and standard deviations of leaf width. Two of the 150 F_3 families had mean leaf widths which fell within the limits indicated by Black Mesdag but they had standard deviations that fell outside the limits marked by this parent.

Considering all the data on leaf width, it is apparent that this character is a variable one and for purposes of making a more exact analysis of its inheritance larger F_3 families should have been grown. For such a study it would be highly desirable to carry the analysis through the F_4 and subsequent generations. The data presented, however, do seem to justify the conclusion that leaf width is a definitely inherited character and that the manner of its inheritance is dependent upon more than one factor difference.

INHERITANCE OF NUMBER OF CULMS

The inheritance of number of culms was studied in 1923 only, as in 1924 the difference between the two parents with respect to this character was not clearly defined, owing largely to seasonal influence. In 1923 the mean number of culms of 443 Gopher plants was 7.12 ± 0.11 and of 381 Black Mesdag plants was 4.45 ± 0.08. In 1924 the mean number of culms of 328 Gopher plants was 3.16 ± 0.04 and of 301 Black Mesdag plants 2.36 ± 0.03.

The frequency distributions of number of culms of the F_3 plants and the parents which were grown with them in 1923 are shown in Table 23.

It may be noted that there are 68 and 62 plants of Gopher and Black Mesdag, respectively, reported as growing with the F_2 generation in 1923, whereas in Table 15, in connection with the leaf width study, there were but 49 plants of each parent reported. The reason for the smaller number of plants in the latter case is that in 1923 only those parental plants were measured for leaf width which had three upper leaves whose width could be determined. If the lower leaf had withered the plant was eliminated.

TABLE 23.—Frequency Distributions of Number of Culms of Individual Plants for the F_2 and the Parents of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Number of Culms																	n	m	σ
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17			
Gopher	1	0	11	9	5	9	9	5	5	3	4	2	3	2				68	6.79±0.26	3.19±0.18
Black Mesdag	4	9	12	11	10	5	2	5	1	1	0	1	1					62	4.52±0.22	2.54±0.15
F_2 Family	5	14	29	60	73	77	45	53	41	24	9	8	9	5	1	1	1	455	6.52±0.09	2.73±0.06

TABLE 24.—Frequency Distributions of the Mean Number of Culms for the Parents and F_3 Progenies of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Mean Number of Culms																			
	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	12.25	12.75
Gopher					1	1	3	4	4	3	0	0	2	0	0	0	0	0	0	1
Black Mesdag	2	4	3	5	0	2	1													
F_3 Families			10	17	21	25	34	19	10	4	3	4								

It may be seen from Table 23 that the modes of the distributions for number of culms in the two parents correspond, although there were relatively few plants of Black Mesdag with a large number of culms. The means of the number of culms of Gopher and Black Mesdag were 6.79 ± 0.26 and 4.52 ± 0.22, respectively, whereas, the mean number of culms of the F_2 generation was 6.52 ± 0.09. The behavior of the F_2 generation seems to indicate that a high number of culms was inherited as a dominant character. It is apparent, too, that the number of culms was a variable character and one that was probably influenced considerably by environment.

That the number of culms is an inherited character, is more clearly shown by the data obtained from the F_3 families. In Table 24 the frequency distributions of the mean number of culms of the F_3 families and the parents which were grown with them are shown. It is obvious that some of the F_3 families bred like the Gopher parent with respect to mean number of culms and other F_3 families like the Black Mesdag parent.

INHERITANCE OF COLOR OF SEED

The Gopher parent of the oat crosses discussed in this bulletin had white seed and the Black Mesdag had black seed. The seeds of the F_1 plants were black but not quite of the same intensity as the seed of the black parent. Of the 455 F_2 plants grown in 1923, 355 had black seed and 100 had white seed. The deviation from expectation on a monohybrid basis was 13.7 ± 6.2. In 1924 there were 622 F_2 individuals, of which 483 were black-seeded and 139 were white-seeded plants. In this case the deviation from monohybrid expectation was 16.5 ± 7.3.

Additional evidence concerning the inheritance of seed color in this oat cross may be obtained from the F_3 generation grown in 1924. In all there were 150 F_3 families grown during this year. Of this number 40 bred true for black seed, 79 segregated for seed color, and 31 bred true for white seed. This result is in fairly close ($P = 0.4856$) agreement with expectation, on the assumption that the parents differed in regard to seed color by a single factor.

INTERRELATION OF HERITABLE CHARACTERS

The relation of one character to another is of importance. If two characters are closely linked in their inheritance, and it is desirable to break this linkage, it is necessary to grow a greater number of offspring than is the case if the two characters are independent in

their inheritance. A study of the relation in inheritance of the four characters herein considered was made.

Seed Color and Other Characters

In Table 25 are presented the data based on the F_2 generation grown in 1923 which bring out the relationships between color of seed and the other three characters. The reciprocals, although no difference was observed between them, have been kept separate in this table.

The difference between the mean dates of heading for the black-seeded and the white-seeded F_2 plants of Gopher × Black Mesdag was 2.34±0.35, and of Black Mesdag × Gopher, 1.21±0.57, both instances being in favor of white-seeded plants. The former difference is significant in the light of its probable error, but the latter is not. Since the black-seeded parent was also the later parent, the significant difference obtained was certainly not due to close genetic linkage.

With respect to mean number of culms the black-seeded and white-seeded F_2 plants did not differ significantly from one another in either the Gopher × Black Mesdag or the reciprocal cross.

The F_2 plants with black seed of Gopher × Black Mesdag had a mean leaf width of 15.39±0.11, whereas the plants with white seed had a mean leaf width of 16.69±0.20. The difference of 1.30±0.23 between these means is more than five times its probable error. The difference between the means of leaf width of the black-seeded and white-seeded F_2 plants of Black Mesdag × Gopher is not significant. Black seeds and wide leaves were associated in one of the parents of this cross so it is apparent that there is no evidence of linkage here.

The data obtained from the F_2 generations grown in 1924 are recorded in Table 26. Here again there is no evidence of a genetic linkage between the several character pairs as they entered the cross. In the Black Mesdag parent, black seed was associated with late maturity, a small number of culms, and wide leaves, as contrasted with the Gopher parent in which white seed was associated with early maturity, a large number of culms, and narrow leaves. In view of the evidence presented, it may be concluded that color of seed is not linked in inheritance with any of the other characters studied in this investigation.

Leaf Width and Number of Culms

The relation in inheritance of leaf width to number of culms was studied by determining the degree of correlation between these characters in the F_2 generation as compared with the parents. Unfortunately, the relation between these two characters was not determined

TABLE 25.—The Relation Between Color of Seed and Certain Characters—Date of Heading, Number of Culms, and Leaf Width—in the F_2 Generation of Gopher × Black Mesdag and the Reciprocal Grown in 1923.

Names of Strains	Color of Seed	Dates of Heading*										n	m
		6/16	6/18	6/20	6/22	6/24	6/26	6/28	6/30	7/2	7/4		
Gopher x Bl. Mes. F_2..	Black	37	38	20	26	32	59	31	8	0	1	252	22.59±0.19
Gopher x Bl. Mes. F_2..	White	4	4	3	6	9	23	16	6			71	24.93±0.30
Bl. Mes. x Gopher F_2..	Black	16	14	5	9	17	20	16	6			103	22.93±0.30
Bl. Mes. x Gopher F_2..	White	3	2	1	3	1	14	4	1			29	24.14±0.49

		Number of Culms																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
Gopher x Bl. Mes. F_2..	Black	2	6	22	32	38	43	29	25	26	12	4	5	4	3	0	1		252	6,46±0.11
Gopher x Bl. Mes. F_2..	White	1	2	4	14	10	11	5	10	4	5	1	1	1	1	1			71	6.41±0.23
Bl. Mes. x Gopher F_2..	Black	2	4	3	11	17	18	8	17	7	5	4	2	3	1	0	0	1	103	6.79±0.19
Bl. Mes. x Gopher F_2..	White		2	0	3	8	5	3	1	4	2	0	0	1					29	6 34±0 31

		Widths of Leaves in Millimeters																	
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Gopher x Bl. Mes. F_2..	Black	1	5	5	22	30	31	40	40	24	18	22	9	4	1			252	15.39±0.11
Gopher x Bl. Mes. F_2..	White			1	3	1	9	11	8	12	7	10	5	2	2			71	16.69±0.20
Bl. Mes. x Gopher F_2..	Black		1	0	5	8	18	19	12	16	11	9	0	2	0	1	1	103	15.89±0.17
Bl. Mes. x Gopher F_2..	White				1	1	1	8	3	7	4	3	0	1				29	16.41±0.24

*Given as month and day; thus 6/16 means June 16.

TABLE 26.—The Relation Between Color of Seed and Certain Characters—Date of Heading, Number of Culms, and Leaf Width—in the F_2 Generation of Gopher × Black Mesdag and the Reciprocal Grown in 1924.

Names of Strains	Color of Seed	Dates of Heading*														n	m
		6/28	6/29	6/30	7/1	7/2	7/3	7/4	7/5	7/6	7/7	7/8	7/9	7/10	7/11		
Gopher x Bl. Mes. F_2	Black	6	9	16	43	20	65	36	5	27	0	5	0	2		234	2.77±0.10
Gopher x Bl. Mes. F_2	White	1	1	4	3	5	30	16	1	8	0	4	0	1		74	3.50±0.16
Bl. Mes. x Gopher F_2	Black		3	5	15	18	43	75	9	49	5	21	0	5	1	249	4.34±0.09
Bl. Mes. x Gopher F_2	White			1	3	1	15	12	6	14	2	10	0	0	1	65	4.88±0.18

		Number of Culms								
		1	2	3	4	5	6	7		
Gopher x Bl. Mes. F_2	Black	34	56	93	41	7	2	1	234	2.75±0.05
Gopher x Bl. Mes. F_2	White	12	14	32	16				74	2.70±0.08
Bl. Mes. x Gopher F_2	Black	41	88	81	34	5			249	2.49±0.04
Bl. Mes. x Gopher F_2	White	9	22	24	10				65	2.54±0.08

		Widths of Leaves in Millimeters																						
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	30		
Gopher x Bl. Mes. F_2	Black		3	4	5	1	4	7	14	14	18	23	29	24	36	18	13	8	11	2			234	19.97±0.16
Gopher x Bl. Mes. F_2	White			2	1	0	2	2	4	6	3	2	9	10	11	8	5	5	2	2			74	20.50±0.28
Bl. Mes. x Gopher F_2	Black	1	2	3	2	4	3	8	19	22	23	34	36	19	23	22	13	11	3			1	249	19.53±0.14
Bl. Mes. x Gopher F_2	White		1	1	1	3	1	2	2	6	11	7	6	8	7	1	5	1	0	1	1		65	19.18±0.30

*Given as month and day; thus 6/28 means June 28.

for the parents in 1923, but it was determined for them in 1924. The results are tabulated in Table 27.

TABLE 27.—The Correlation Between Leaf Width and Number of Culms in the F_2 Generation of Gopher × Black Mesdag and the Reciprocal as Compared with the Parents.

Names of Strains	Year Grown	n	r
Gopher x Black Mesdag F_2	1923	323	$+0.30 \pm 0.03$
Black Mesdag x Gopher F_2	1923	132	$+0.24 \pm 0.06$
Gopher x Black Mesdag F_2	1924	308	$+0.41 \pm 0.03$
Black Mesdag x Gopher F_2	1924	314	$+0.41 \pm 0.03$
Gopher P_1	1924	328	$+0.53 \pm 0.03$
Black Mesdag P_1	1924	301	$+0.47 \pm 0.03$

From the last column of Table 27, it is obvious that there is a positive correlation between leaf width and number of culms both in the F_2 generations and the parents. Considering only the plants that were grown in 1924, we find that the magnitude of the coefficients of correlation between leaf width and number of culms in the reciprocal F_2 generations is identical and that the magnitude of the coefficients for these same characters in the parents is somewhat greater although not significantly so. In 1923 the correlation between leaf width and number of culms was not as marked as in 1924. The foregoing correlations are somatic and not genetic since broad leaves and few culms, and narrow leaves and many culms were associated in the parents.

Leaf Width and Date of Heading

The relation in inheritance between leaf width and date of heading was also studied by means of correlation. In the parents broad leaves were associated with late maturity and narrow leaves with early maturity. In Table 28 are recorded the correlation coefficients obtained for these characters in the parents of the F_2 generations.

In 1923 the correlation between leaf width and date of heading was sensibly zero in both F_2 crosses, whereas in 1924 there was a slight negative correlation between these two characters in the F_2 generations. The parents which were studied in 1924 only, showed a somewhat higher negative correlation between leaf width and date of heading than did the F_2 generations grown the same year. These data certainly show there was no close linkage between leaf width and date

TABLE 28.—The Correlation Between Leaf Width and Date of Heading in the F_2 Generation of Gopher × Black Mesdag and the Reciprocal as Compared With the Parents.

Names of Strains	Year Grown	n	r
Gopher x Black Mesdag F_2	1923	323	$+0.08\pm0.04$
Black Mesdag x Gopher F_2	1923	132	$+0.07\pm0.06$
Gopher x Black Mesdag F_2	1924	308	-0.15 ± 0.04
Black Mesdag x Gopher F_2	1924	314	-0.29 ± 0.03
Gopher P_1	1924	328	-0.44 ± 0.03
Black Mesdag P_1	1924	301	-0.50 ± 0.03

of heading in this oat cross. Environment seems to have influenced the correlation of these characters to some extent as is indicated by the difference obtained between the coefficients for the F_2 generations in 1923 and in 1924.

Date of Heading and Number of Culms

The Gopher parent was earlier in heading and had a relatively larger number of culms than the Black Mesdag parent. If these two characters are linked in inheritance one would expect a negative correlation between date of heading and number of culms in the F_2 generation. Such a negative relation was found as is shown in Table 29. Before drawing conclusions based entirely on the F_2 generation, however, it is necessary to know something of the relation between

TABLE 29.—The Correlation Between Date of Heading and Number of Culms in the F_2 Generation of Gopher × Black Mesdag and the Reciprocal as Compared With the Parents.

Names of Strains	Year Grown	n	r
Gopher x Black Mesdag F_2	1923	323	-0.38 ± 0.03
Black Mesdag x Gopher F_2	1923	132	-0.32 ± 0.05
Gopher x Black Mesdag F_2	1924	308	-0.20 ± 0.04
Black Mesdag x Gopher F_2	1924	314	-0.36 ± 0.03
Gopher P_1	1924	328	-0.54 ± 0.03
Black Mesdag P_1	1924	301	-0.38 ± 0.03

these two characters in each parent. Such a study was made in 1924 but not in 1923.

It is obvious from the last column of Table 29 that a negative correlation between date of heading and number of culms was found in the F_2 generations grown in both 1923 and 1924, but it is also evident that the negative correlation between these same characters in the parents was just as marked (in one case more so) as the negative correlations in the F_2 generations grown the same year. Apparently, there is no linkage between date of heading and number of culms.

SUMMARY AND CONCLUSIONS

1.—The F_2, F_3, and in some cases the F_1 generations of certain oat crosses Gopher × Black Mesdag and the reciprocal were studied during two years to determine the inheritance of date of heading, leaf width, number of culms, and color of seed. In all, there were grown in 1923 6 F_1 plants, 455 F_2 plants, and 139 F_3 families, and in 1924 there were grown 622 F_2 plants and 150 F_3 families. The parents were grown at regular intervals among the progeny in both years of the experiment.

2.—Earliness was found to be inherited as a dominant character and some evidence was obtained which indicated that in this particular cross there were at least two factor differences concerned.

3.—Leaf width determined at the widest part of the leaf proved to be a variable character and one that was influenced to a marked degree by environment. On the basis of a preliminary study the second leaf, numbering from the top down, was found to be most satisfactory for measuring. Data are presented to show that leaf width is an inherited character, but the manner of its inheritance was not determined. The distribution obtained in the F_2 generation and the behavior of the F_3 families with respect to leaf width was rather typical of what occurs when a cross is made involving a quantitative character dependent on multiple factors for its expression. One F_3 family grown in 1924 had a mean leaf width significantly less than the mean leaf width of any plot of Gopher, the narrow-leaved parent.

4.—Number of culms, like leaf width, is a character which is greatly influenced by environment. In 1923 the difference between the mean number of culms of Gopher and Black Mesdag was much grown in 1923 show that number of culms is an inherited character. greater than the difference in 1924. Data on the F_2 and F_3 generations

5.—Black seed color in the cross reported here was found to be dominant to white seed color, and was found to be dependent upon a single factor difference for its inheritance.

6.—No positive evidence of close linkage was found between any two of the four characters studied, namely, date of heading, leaf width, number of culms, and color of seed.

APPENDIX

The planting plan showing the arrangement of the plots on which the F_3 families and the parents were grown in 1924 is indicated in Table 30, and also in Table 31. The end of each series is marked by a heavy line. The plots were numbered consecutively and in one direction only; thus the first plot of the first series was just opposite, and across the alley from, the first plot of the second series. In Table 30 the frequency distributions of date of heading of the F_3 families and the parents grown with them are shown, and the frequency distributions of leaf width for the same plants are given in Table 31.

TABLE 30.—Frequency Distributions of Date of Heading of the F_3 Families and the Parents of Gopher × Black Mesdag and the Reciprocal Grown in 1924. The Planting Plan is Indicated by the Arrangement of the Strains.

Names of Strains	Dates of Heading (1 = June 26)																		n
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Bl. Mes. P_1												2	8	9	15	0	6		40
Gopher P_1					8	11	6	15	2										42
17-6-26 F_3			1		6	3	4	17	4	1	3								39
17-6-2 F_3				1		2	1	8	13	2	4	2							33
17-6-3 F_3								4	4	9	21	1	7	1					47
17-6-4 F_3								2	2	11	14	1	10						40
17-6-5 F_3									1	0	1	5	6	4	16	1	4	1	9
Bl. Mes, P_1												5	3	4	17	1	10	1	41
Gopher P_1					6	18	5	12	1	1									43
17-6-6 F_3								2		3	8	10	18	2					43
17-6-7 F_3				1	2	4	4	13	11	2	5	1							43
17-6-8 F_3					1	3	0	5	8	4	12	4	6						43
17-6-9 F_3			1	0	4	6	11	20	1										43
17-6-10 F_3						2	2	12	12	7	10	1							46
Bl. Mes. P_1												1	11	2	21	1	6		42
Gopher, P_1					7	11	5	15	5										43
17-6-11 F_3						1			4	2	8	6	5				1		27
17-6-12 F_3					1	4	2	7	17	1	11	2							45
17-6-13 F_3					2	1	0	6	20	3	5								37
17-6-14 F_3					2	5	7	19	6	4									43
17-6-15 F_3			1	4	5	12	2	9	1	2	2								38
Bl. Mes. P_1												5	3	1	23	0	3		35
Gopher P_1			1	3	9	19	4	8											44
17-6-16 F_3			3	3	1	6	1	15	9	4									42
17-6-17 F_3			5	6	9	10	3	9											42
17-6-18 F_3				1	2	9	4	13	14	2									45
17-6-19 F_3	2	2	4	9	10	8	2	2											39
17-6-30 F_3									4	13	16	0	9	0	2	1			45
Bl. Mes. P_1												5	15	11	14		6		41
Gopher P_1					2	7	6	25	1										41
17-6-27 F_3						1			9	5	15	1	10		1				42
17-6-31 F_3								1	6	6	6	6	14	1	6				46
17-6-23 F_3				1	4	7	3	26	3	1									45
17-6-24 F_3		1	0	1	4	15	3	19	3										46
17-6-25 F_3					3	9	4	20	2	0	2								40
Bl. Mes. P_1												5	7	4	11	1	2		30
Gopher P_1				1	5	8	2	10	4	5									35
17-7-26 F_3			1	2	5	6	5	19	3	2	1								44
17-7-2 F_3				1	2	5	1	5	15	4	5		3						41
17-7-3 F_3					2	2	1	8	15	0	12	2							42
17-7-4 F_3								2	3	5	9	3	16	21	2	1	2		44
17-7-5 F_3						2	1	3	12	4	12	0	5	0	2	0	0	1	42

(Continued)

TABLE 30.—Continued.

Names of Strains	Dates of Heading (1 = June 26) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	n
Bl. Mes. P_1													13	0	14	1	4	4	36
Gopher P_1						14	1	23	2										40
17-7-6 F_3							1	7	18	3	7		3						39
17-7-7 F_3				12	12	19	0	4											47
17-7-8 F_3								3	4	6	13	3	14	1					44
17-7-9 F_3						3	1	4	9	1	9		8	1	2				38
17-7-10 F_3									2	2	3	5	20	1	3	0	1		37
Bl. Mes. P_1												2	7	3	24	1	2	2	41
Gopher P_1					3	15	0	15	9	2									44
17-7-11 F_3					1	1	0	5	25	4	1								37
17-7-12 F_3					2	9	3	19	12	0	1								46
17-7-13 F_3								6	9	5	11	1	3	1					36
17-7-29 F_3							1	3	14	3	15		7			2			45
17-7-15 F_3				1	4	12	3	17	5										42
Bl. Mes. P_1												5	11	2	14	2	3		37
Gopher P_1					2	11	2	16	2	1	1								35
17-7-16 F_3					3	3	2	3	18		2								31
17-7-17 F_3				1	1	7	2	18	8	0	1								38
17-7-18 F_3						7	1	8	18	3	2	1							40
17-7-19 F_3						3	1	2	7	4	15	2	4	1					39
17-7-20 F_3				1	0	2	1	3	13	2	11	1	4	1	1				40
Bl. Mes. P_1													3	1	20	2	8	1	35
Gopher P_1				2	1	9	6	11	10	2	1								42
17-7-21 F_3				2	1	8		4	7	2	7	2	4	1					38
17-7-27 F_3			1		4	4	0	8	4	1	3		5						30
17-7-23 F_3					1	9	0	8	15	0	5	0	2						40
17-7-24 F_3					1	3	0	10	14	1	4	0	2	0	2				37
17-7-25 F_3					3	8		6	16		1		1	1	1				37
Bl. Mes. P_1												1	10	0	18	0	5		34
Gopher P_1					1	16	2	19	3	2									43
17-8-26 F_3				1	3	15	5	17	7	1									49
17-8-2 F_3								3	9	2	12	2	14	2	1				45
17-8-3 F_3			1			6	2	6	26	1	3								45
17-8-4 F_3						2	0	8	14	1	5	2							32
17-8-5 F_3								3	7	1	9	1	12						33
Bl. Mes. P_1													2	1	32	1	8		44
Gopher P_1					1	9	0	17	16	0	2								45
17-8-6 F_3								1	9	2	12	4	12						40
17-8-7 F_3						0	1	5	15	6	12	0	1						40
17-8-8 F_3					1	1	1	2	12	2	4	2	7	0	1				33
17-8-9 F_3			2	1	1	9	7	14	3		2								39
17-8-10 F_3			1	2	5	17		11	3	1									40
Bl. Mes. P_1													13	1	18	1	3	1	37
Gopher P_1			2	2	6	17	5	10	2	1									45
17-8-11 F_3					1	6	5	12	12	4	1								41
17-8-12 F_3					4	10	4	14	11	1									44
17-8-13 F_3					3	6		17	17	1									44
17-8-14 F_3				4	6	15	2	8	3		2								40
17-8-15 F_3						1	2	4	20	4	8	2	3						44

(Continued)

TABLE 30.—Continued.

Names of Strains	Dates of Heading (1 = June 26)																		n
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Bl. Mes. P_1..........												7	21	3	6	1	1		39
Gopher P_1..........					1	28	6	10											45
17-8-16 F_3..........						1		1	1	6	3	3	14	2	4	0	5	1	41
17-8-17 F_3..........			1	2		8	5	10	16		1								43
17-8-18 F_3..........						2		7	16	2	11	3							41
17-8-27 F_3..........									3	2	2	3	13	2	9	0	1	3	38
17-8-28 F_3..........											6	1	15	3	11		1	1	38
Bl. Mes. P_1..........													2		9	1	19	5	36
Gopher P_1..........						4		10	17	2	1	2							36
17-8-21 F_3..........									9	1	14		6	3	2	1			36
17-8-22 F_3..........									1	4	11		15		3		1		35
17-8-23 F_3..........						2	0	1	8	2	10		11				1		35
17-8-24 F_3..........					4	6	5	10	18	0	1								44
17-8-25 F_3..........					1	2	3	5	15	1	6	1	3						37
Bl. Mes. P_1..........														3	11	4	17	3	38
Gopher P_1..........							1	7	23	2	2	1							36
16-6-26 F_3..........			4	6	11	9	2	11	1	1	1								46
16-6-2 F_3..........									3	5	14	1	15	1					39
16-6-3 F_3..........						4		10	23	1									40
16-6-4 F_3..........					1	2	0	6	18	3	5								35
16-6-5 F_3..........						1			2	2	12	8	14		4				43
Bl. Mes. P_1..........													5	2	11	2	8	1	29
Gopher P_1..........					1	5	5	4	23	0	2								40
16-6-6 F_3..........			2	0	4	13	0	9	5										33
16-6-7 F_3..........					2	1	3	6	26	3	4	1							46
16-6-8 F_3..........			2		2	3	3	5	8	0	3	0	5	1	1				33
16-6-9 F_3..........									6	0	6	4	14		5	1			36
16-6-10 F_3..........						5		3	7	1	2		2						20
Bl. Mes. P_1..........												1	11	2	18		4		36
Gopher P_1..........					1	11	6	14	6	3									41
16-6-11 F_3..........								2	1	4	10	4	15			1			37
16-6-12 F_3..........								2	4	8	16	0	7						37
16-6-13 F_3..........						1		8	19	1	2		5			2			38
16-6-27 F_3..........					2	5	3	4	15	1	5	1	6						42
16-6-15 F_3..........					1	12	2	11	13	0	1								40
Bl. Mes. P_1..........												2	22	1	4	1	2	3	35
Gopher P_1..........					7	19		11	3	1									41
16-6-16 F_3..........						2		5	18	1	6	2	4	1					39
16-6-28 F_3..........					1	4		11	15	1	7	1	4	1					45
16-6-18 F_3..........										1	2	7	9	1	16	5			41
16-6-19 F_3..........					1	5	3	11	10	1			1		2				34
16-6-20 F_3..........							1	1	14	1	7	1	9	1		1			36
Bl. Mes. P_1..........													8	3	20	0	8	1	40
Gopher P_1..........						12	7	11	11	3	1								45
16-6-21 F_3..........			1	0	0	1	1	7	13	4	7	1	7						42
16-6-22 F_3..........						4	1	1	14	7	12		4						43
16-6-23 F_3..........					3	12		14	11		3								43
16-6-29 F_3..........					3	9	4	16	12	0	2								46
16-6-25 F_3..........								7	6	5	11	2	6		2				39

(Continued)

TABLE 30.—Continued.

Names of Strains	Dates of Heading (1 = June 26) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	n
Bl. Mes. P_1..........												3	8	3	21		7		42
Gopher P_1...........			1		4	9	2	15	13										44
16–7–26 F_3.........											6	10	24	0	1				41
16–7–2 F_3...........						4	0	5	12	5	6		8						40
16–7–3 F_3...........			4	5	3	18	3	8		1									42
16–7–4 F_3...........					11	12	8	14	2										47
16–7–5 F_3...........					3	7	7	18	10	1									46
Bl. Mes. P_1..........											5	12	16	0	7				40
Gopher P_1...........					2	17	8	15	1	1									44
16–7–6 F_3...........			3	1	3	10	3	22	3										45
16–7–7 F_3...........			7	2	11	21	1	1											43
16–7–8 F_3...........					2	13	6	10	14										45
16–7–9 F_3...........									1	2	4	11	22						40
16–7–10 F_3..........							6	17	16	1	1								41
Bl. Mes. P_1..........													11	1	16		5	6	39
Gopher P_1...........						2	1	5	17		6								31
16–7–11 F_3..........									3		1	4	14	1	3	0	2	2	30
16–7–12 F_3..........									1	1	5	7	19	0	2				35
16–7–13 F_3..........												2	2	5	18	1	5	8	41
16–7–14 F_3..........						3	0	2	5	3	7	3	4		2				29
16–7–15 F_3..........									5	1	16	1	9		3				35
Bl. Mes. P_1..........																4	14	17	35
Gopher P_1...........						1		6	15	2	2		2						28
16–7–16 F_3..........								2	2	1	9	3	11	1	3				32
16–7–27 F_3..........					4	15	2	9	8		4								42
16–7–28 F_3..........								4	15		11	4	7		2				43
16–7–19 F_3..........										2	6	9	12		6	3			38
16–7–20 F_3..........						2	4	7	14		6	3	2			1			39
Bl. Mes. P_1..........												1	9	2	23				35
Gopher P_1...........					2	16	3	17	1	1									40
16–7–21 F_3..........							1	4	6		8	2	16			3			40
16–7–22 F_3..........								3	6	1	6	16	11		2				45
16–7–23 F_3..........								11	9	2	14	1	6						43
16–7–24 F_3..........				2	2	25	8	5											42
16–7–25 F_3..........						1		4	11	4	14	1	6						41
Bl. Mes. P_1..........											2	5	12	5	11		1	2	38
Gopher P_1...........						9	7	13	5		5								39
16–8–26 F_3..........									2	2	3	7	14		3	4			35
16–8–2 F_3...........								1	3	2	9	10	16						41
16–8–3 F_3...........					1	10	2	16	13	1	3								46
16–8–4 F_3...........							1	15	16	1	4	2	4						43
16–8–5 F_3...........								4	2	1	6	7	13						33
Bl. Mes. P_1..........											3	9	9	0	10	1			32
Gopher P_1...........			1	1	5	21	5	12											45
16–8–6 F_3...........					1	3		12	12	6	5								39
16–8–7 F_3...........				1	3	7	5	12	11		1								40
16–8–8 F_3...........					1	19	3	13	6	1									43
16–8–9 F_3...........	1		2	1	3	14	6	16	1										44
16–8–10 F_3..........					1	4	3	11	17	2	2								40

(Continued)

TABLE 31.—Concluded.

Names of Strains	Dates of Heading (1 = June 26)																		n
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Bl. Mes. P_1											2	1	8	1	23	3	5		43
Gopher P_1					1	7	5	10	13	1	3								40
16-8-11 F_3						5	2	11	23	0	3								44
16-8-12 F_3						2		5	10	7	18	1	5						48
16-8-13 F_3					1			5	16	3	14	1							40
16-8-14 F_3	1	1			2	4	1	7	29	2									47
16-8-15 F_3				2	2	8	4	3	6	3	3								31
Bl. Mes. P_1											2	13	11		10	1	1	2	40
Gopher P_1					5	18	2	12	8										45
16-8-16 F_3						3	1	4	9	1	14	2	8	0	2				44
16-8-17 F_3						16	3	7	13	1	2								42
16-8-18 F_3			1	1	3	8	1	17	13										44
16-8-19 F_3										5	11	5	16		6	1			44
16-8-20 F_3												3	5	3	28	2	5	1	47
Bl. Mes. P_1											2	6	9	3	14		1	1	36
Gopher P_1					2	20	2	18											42
16-8-21 F_3				2	5	12	3	12	10	1	1								46
16-8-22 F_3						6	1	14	16		4								41
16-8-23 F_3					2	13	1	18	6		1								41
16-8-24 F_3			1	1	2	9	5	13	7	2	3								43
16-8-25 F_3			1	1	1	10	6	15	11		2								47
Bl. Mes. P_1											1	7	6	5	16	2	2		39
Gopher P_1					1	16	3	18	4										42

TABLE 31.—Frequency Distributions of Leaf Width for the F_3 Families and the Parents of Gopher × Black Mesdag and the Reciprocal Grown in 1924. The Planting Plan Is Indicated by the Arrangement of the Strains.

Names of Strains	Leaf Widths in Millimeters																									
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	n
Bl. Mes. P_1									2	2	0	0	5	6	3	4	2	9	4	3						40
Gopher P_1							1	4	7	10	8	4	5	3												42
17-6-26 F_3				1	0	1	4	1	6	3	12	6	0	2	2	0	1									39
17-6-2 F_3							2	0	1	1	4	1	3	4	6	8	2	1								33
17-6-3 F_3								1	1	0	2	3	3	5	6	5	9	7	3	1	0	0	1			47
17-6-4 F_3					1	1	0	1	0	1	0	2	2	4	5	3	5	5	2	5	2	0	1			40
17-6-5 F_3				1	0	1	1	1	3	6	1	3	7	4	7	2	0	1	0	0	0	0	1			39
Bl. Mes. P_1									2	0	1	3	6	5	5	5	4	2	4	3	1					41
Gopher P_1							4	2	6	10	5	10	5	1												43
17-6-6 F_3				1	0	5	2	2	8	8	9	4	1	2	0	0	0	1								43
17-6-7 F_3						1	0	0	4	1	3	4	5	4	6	4	7	1	2	1						43
17-6-8 F_3					1	0	3	1	7	0	5	2	9	6	5	2	0	2								43
17-6-9 F_3								1	1	2	3	7	9	9	4	3	0	3	0	0	1					43
17-6-10 F_3					1	1	1	0	1	4	3	3	6	9	6	4	4	2	1							46
Bl. Mes. P_1									1	0	2	3	3	7	7	5	5	5	2	0	1	1				42
Gopher P_1		1	1	0	0	1	3	2	12	7	8	5	2	1												43
17-6-11 F_3				1	0	1	2	1	2	4	5	2	5	1	2	0	1									27
17-6-12 F_3					1	1	2	5	4	6	12	4	4	2	3	1										45
17-6-13 F_3							1	0	4	1	4	3	6	2	7	2	2	5								37
17-6-14 F_3								1	3	5	6	5	7	8	3	3	2									43
17-6-15 F_3				2	1	0	1	3	5	9	8	2	5	1	1											38
Bl. Mes. P_1									1	1	0	3	1	2	5	4	7	4	4	1	2					35
Gopher P_1							2	7	5	9	8	5	5	1	2											44
17-6-16 F_3					2	0	0	0	3	5	6	10	3	4	1	3	2	1	1	0	0	0	0	0	1	42
17-6-17 F_3					1	1	4	1	5	4	10	6	4	1	5											42
17-6-18 F_3		1	1	1	0	1	6	6	16	5	6	2														45
17-6-19-F_3					1	1	0	4	9	10	3	3	5	1	1	1										39
17-6-30 F_3							1	0	1	2	2	3	1	5	5	9	5	6	3	1	0	1				45

(Continued)

TABLE 31.—Continued.

Names of Strains	Leaf Widths in Millimeters																								n
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
Bl. Mes. P_1						1	1	1	1	1	5	2	4	2	5	4	3	5	4	1	0	1				41
Gopher P_1						2	4	5	9	10	7	3	0	1												41
17-6-27 F_3				3	2	1	1	0	0	5	1	8	2	4	6	2	2	3	1	1						42
17-6-31 F_3				1	2	4	3	8	6	5	10	1	4	0	1	1										46
17-6-23 F_3					1	0	2	1	1	2	6	6	9	5	6	2	1	3								45
17-6-24 F_3							1	1	0	2	7	6	6	8	7	4	3	1								46
17-6-25 F_3					1	0	0	5	3	3	6	7	7	4	2	0	1	1								40
Bl. Mes P_1					1	2	0	1	2	1	0	5	3	3	4	2	1	3	2							30
Gopher P_1	2	0	3	1	2	2	5	1	5	4	4	3	2	0	0	1										35
17-7-26 F_3					2	0	2	1	3	7	8	10	2	3	4	0	1	0	1							44
17-7-2 F_3					1	2	1	2	4	7	3	6	8	5	2											41
17-7-3 F_3				1	0	0	4	2	5	2	12	9	3	3	0	1										42
17-7-4 F_3						2	1	0	1	2	4	4	3	3	7	7	4	3	1	1	0	1				44
17-7-5 F_3			1	0	3	1	2	5	8	5	4	6	2	3	1	1										42
Bl. Mes. P_1							2	0	3	2	1	3	2	5	7	3	5	1	1	0	0	0	0	1		36
Gopher P_1						2	1	5	4	13	9	6														40
17-7-6 F_3					2	1	2	2	6	3	3	5	6	7	1	1										39
17-7-7 F_3					1	2	3	7	10	9	11	2	2													47
17-7-8 F_3					1	2	0	2	3	9	12	5	8	2												44
17-7-9 F_3						2	0	2	1	2	4	3	2	7	6	6	2	0	0	0	1					38
17-7-10 F_3				1	2	3	5	6	7	6	3	4														37
Bl. Mes. P_1							1	0	1	3	2	4	2	3	7	4	10	3	1							41
Gopher P_1						2	5	5	8	13	9	2														44
17-7-11 F_3						1	1	5	7	5	5	3	5	4	1											37
17-7-12 F_3				1	1	0	1	0	4	10	5	9	6	4	3	1	0	1								46
17-7-13 F_3			1	1	1	1	1	0	2	3	8	6	6	2	0	1	2	1								36
17-7-29 F_3				1	0	1	0	1	2	1	0	3	7	6	9	4	5	5								45
17-7-15 F_3						1	3	3	4	6	10	5	5	3	1	1										42

Bl. Mes. P_1							1	0	1	1	1	2	1	3	7	6	3	6	5							37
Gopher P_1						3	4	6	8	3	3	5	2	0	1											35
17-7-16 F_3								1	1	4	2	2	7	3	5	2	3	1								31
17-7-17 F_3				1	0	0	0	2	10	10	4	7	3	1												38
17-7-18 F_3				1	1	0	0	1	1	4	2	8	7	5	6	2	1	1								40
17-7-19 F_3					1	0	2	1	2	4	6	6	8	2	1	4	2									39
17-7-20 F_3		1	0	2	0	2	1	0	4	7	8	1	4	7	2	1										40
Bl. Mes. P_1						1	2	1	4	1	2	2	3	2	4	3	4	2	3	1						35
Gopher P_1				1	0	0	4	7	6	8	7	5	3	1												42
17-7-21 F_3				2	1	3	5	1	4	2	5	3	5	2	3	0	2									38
17-7-27 F_3					1	2	2	1	4	5	3	2	5	2	1	0	1	1								30
17-7-28 F_3				2	0	1	4	3	3	5	3	3	5	2	5	3	0	1								40
17-7-24 F_3			1	0	1	0	1	4	2	3	4	6	7	5	2	0	1									37
17-7-25 F_3						1	5	5	6	6	6	5	2	1												37
Bl. Mes. P_1								1	1	1	3	1	3	2	4	4	2	8	3	0	1					34
Gopher P_1			1	2	1	1	7	13	9	4	1	4														43
17-8-26 F_3			1	1	2	3	4	5	5	9	7	6	2	4												49
17-8-2 F_3			1	2	1	2	3	6	6	4	6	3	5	4	2											45
17-8-3 F_3				1	3	3	7	8	17	4	2															45
17-8-4 F_3				1	0	0	5	0	3	6	3	7	4	3												32
17-8-5 F_3						1	2	4	3	2	7	7	2	0	0	2	1	0	0	2						33
Bl. Mes. P_1									1	2	1	1	6	7	9	10	2	3	1	1						44
Gopher P_1				1	3	2	2	8	10	8	3	6	2													45
17-8-6 F_3				1	0	0	0	5	4	1	5	6	9	8	1											40
17-8-7 F_3									3	2	3	4	4	5	4	5	4	1	5							40
17-8-8 F_3							1	1	2	3	4	5	5	2	3	3	4									33
17-8-9 F_3			1	0	0	0	1	2	4	6	4	8	7	6												39
17-8-10 F_3							2	2	4	5	4	7	5	2	6	1	1	1								40
Bl. Mes. P_1											2	4	1	3	7	4	6	9	1							37
Gopher P_1				1	0	2	5	5	8	8	6	7	1	1	1											45
17-8-11 F_3								3	4	7	6	4	7	3	1	1	2	3								41
17-8-12 F_3								2	3	2	2	5	5	5	9	3	6	0	2							44
17-8-13 F_3							1	0	1	1	4	6	7	9	4	2	3	3	1	1	1					44
17-8-14 F_3					2	2	4	2	7	7	3	10	2	1												40
17-8-15 F_3						2	4	0	11	8	3	8	5	1	1	1										44

(Continued)

TABLE 31.—Continued.

Name of Strains	Leaf Widths in Millimeters																								
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	n
Bl. Mes. P_2							2	1	2	1	2	1	4	0	3	5	7	7	2	3						39
Gopher P_1						3	8	5	14	5	4	5	1													45
17-8-16 F_3			1	2	3	1	6	5	9	3	6	4	1													41
17-8-17 F_3						1	0	7	7	8	10	4	4	1	1											43
17-8-18 F_3				2	0	1	0	1	2	1	4	4	4	9	5	5	0	1	1	1						41
17-8-27 F_3					1	2	2	3	2	3	9	5	2	6	2	0	1									38
17-8-28 F_3							2	3	0	1	2	3	2	3	4	3	7	3	2	1	1	0	0	1		38
Bl. Mes. P_1									2	0	4	1	1	4	6	7	5	4	2							36
Gopher P_1					1	3	3	4	7	4	7	4	2	1												36
17-8-21 F_3					1	1	6	3	3	2	4	3	6	1	3	3										36
17-8-22 F_3					1	1	2	3	4	3	5	4	5	1	3	3										35
17-8-23 F_3					1	3	2	2	6	6	7	5	1	0	2											35
17-8-24 F_3					1	0	2	1	5	11	9	10	3	1	1											44
17-8-25 F_3				1	0	1	1	0	2	7	4	5	5	2	4	5										37
Bl. Mes. P_1							2	0	1	2	1	3	1	1	9	7	7	2	1	1						38
Gopher P_1			1	0	2	0	0	1	6	8	7	10	1													36
16-6-26 F_3			1	0	3	4	5	5	9	14	4	1														46
16-6-2 F_3						1	0	1	1	1	4	2	2	5	9	10	1	1	0	1						39
16-6-3 F_3					1	1	4	2	2	8	7	5	3	4	2	1										40
16-6-4 F_3						2	1	0	6	8	4	7	4	2	0	1										35
16-6-5 F_3				1	0	2	0	0	1	6	4	4	6	6	6	3	4									43
Bl. Mes. P_1									2	3	0	5	2	2	2	7	5	1								29
Gopher P_1			1	0	1	1	5	2	13	7	6	3	1													40
16-6-6 F_3			1	4	1	0	4	3	9	5	4	1	0	1												33
16-6-7 F_3				1	0	3	4	1	9	7	4	9	4	2	2											46
16-6-8 F_3	2	6	4	3	4	4	6	2	1	1																33
16-6-9 F_3				1	1	0	2	1	2	4	2	4	6	4	3	4	2									36
16-6-10 F_3		1	0	1	1	1	5	0	4	3	1	1	0	2												20

Bl. Mes. P_1						1	0	1	1	2	1	4	5	4	5	4	5	2	0	0	0	1				36
Gopher P_1					2	3	4	7	6	7	2	3														41
16-6-11 F_3				1	0	0	0	1	0	1	4	2	8	3	3	4	4	5	1							37
16-6-12 F_3					2	0	0	0	0	3	1	6	4	10	4	3	3	0	1							37
16-6 13 F_3				1	0	2	1	2	4	2	7	5	6	5	3											38
16-6-27 F_3			2	1	1	1	1	2	2	5	2	13	6	0	3	1	1	1								42
16-6-15 F_3							1	4	3	4	2	7	5	6	3	3	2									40
Bl. Mes. P_1							2	2	1	1	1	1	3	2	2	6	7	3	2	2						35
Gopher P_1				2	0	5	7	4	6	4	5	5	2	1												41
16-6-16 F_3					2	0	0	1	6	2	6	8	4	3	5	1	0	1								39
16-6-28 F_3							2	2	7	11	9	10	1	2	1											45
16-6-18 F_3				1	4	1	2	5	5	5	5	7	2	0	2	2										41
16-6-19 F_3					1	1	1	3	3	4	7	3	5	2	2	0	1	1								34
16-6-20 F_3			1	0	0	0	6	2	4	5	4	7	4	1	1	1										36
B l Mes. P_1									2	0	1	1	3	4	2	12	10	3	2							40
Gopher P_1			3	3	1	3	2	4	8	12	8	1														45
16-6-21 F_3					1	5	8	6	6	1	8	3	3	0	1											42
16-6-22 F_3			1	0	1	0	2	0	1	3	1	2	6	2	10	8	3	3								43
16-6 23 F_3			1	0	0	1	2	6	6	9	8	4	1	2	2	1										43
16-6-29 F_3						1	1	0	0	0	0	8	11	6	10	2	2	1	3	1						46
16-6-25 F_3							1	0	1	5	5	4	5	6	2	5	3	2								39
Bl. Mes. P_1											2	1	1	3	5	6	11	5	3	5						42
Gopher P_1							2	2	6	5	10	7	7	4	1											44
16 7 26 F_3									1	3	10	6	3	4	4	5	1	1	2	1						41
16-7-2 F_3					1	1	0	0	0	1	1	3	3	5	5	4	4	6	4	0	2					40
16-7-3 F_3								1	2	1	6	6	7	2	12	2	2	1								42
16-7-4 F_3					1	0	0	0	3	1	5	1	2	8	9	4	6	3	3	1						47
17-7-5 F_3					1	2	6	7	6	6	10	2	5	1												46
Bl. Mes. P_1										1	1	6	3	5	8	5	5	2	2	1	1					40
Gopher P_1					3	2	6	5	7	3	11	4	1	1	1											44
16-7-6 F_3						1	1	2	3	2	11	9	5	5	2	3	1									45
16-7-7 F_3			1	0	0	1	1	2	4	7	2	4	7	4	4	2	2	2								43
16-7-8 F_3							2	8	4	7	12	4	5	2	1											45
16-7-9 F_3										1	3	5	7	12	3	5	2	1	1							40
16-7-10 F_3						2	5	3	10	11	6	0	1	0	2	1										41

(Continued)

TABLE 31.—Concluded.

Name of Strains	Leaf Widths in Millimeters																									
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	n
Bl. Mes. P_1								2	1	5	1	4	5	6	8	4	2	1								39
Gopher P_1					2	1	4	7	4	9	2	0	2													31
16-7-11 F_3						1	2	2	2	2	6	1	7	2	4	1										30
16-7-12 F_3							1	0	0	2	6	4	6	3	5	5	2	0	0	1						35
16-7-13 F_3					1	1	5	4	4	10	2	5	6	2	1											41
16-7-14 F_3					3	4	3	4	4	3	2	3	0	1	2											29
16-7-15 F_3					3	0	1	3	6	6	5	6	4	0	1											35
Bl. Mes. P_1					1	0	0	1	4	4	5	3	2	5	1	5	3	0	1							35
Gopher P_1					1	0	1	2	5	4	8	5	2													28
16-7-16 F_3					1	1	1	3	2	5	9	4	4	2												32
16-7-27 F_3							1	0	2	6	5	12	7	6	3											42
16-7-28 F_3							1	0	2	1	0	1	5	6	5	5	9	5	2	1						43
16-7-19 F_3							1	3	0	0	3	5	2	5	8	2	3	3	1	2						38
16-7-20 F_3					1	1	1	1	1	1	3	6	7	5	6	1	2	1	1	1						39
Bl. Mes. P_1											1	2	2	3	6	2	8	4	5	2						35
Gopher P_1								4	6	9	13	5	1	2												40
16-7-21 F_3				1	1	0	3	2	6	9	6	6	2	1	3											40
16-7-22 F_3						1	5	5	6	9	9	6	2	1	1											45
16-7-23 F_3								2	4	12	7	3	5	6	2	1	1									43
16-7-24 F_3				1	0	1	2	3	12	7	9	5	2													42
16-7-25 F_3								3	2	7	7	9	1	7	4	1										41
Bl. Mes. P_1					1	0	0	1	0	4	4	1	4	2	5	7	4	3	2							38
Gopher P_1				1	3	3	3	7	4	5	4	5	3	0	1											39
16-8-26 F_3				1	0	2	1	4	8	5	5	7	0	0	2											35
16-8-2 F_3					1	2	5	3	11	11	5	3														41
16-8-3 F_3					1	2	2	3	8	9	3	9	6	3												46
16-8-4 F_3				1	0	0	0	1	1	2	7	3	6	6	6	5	4	0	1							43
16-8-5 F_3						2	0	0	1	3	2	3	4	6	4	6	0	0	2							33

Bl. Mes P_1							1	0	2	1	4	3	2	4	3	4	5	2	1							32
Gopher P_1						2	5	6	8	9	7	5	2	1												45
16-8-6 F_3				1	0	0	2	3	5	11	7	5	3	2												39
16-8-7 F_3						1	0	3	6	9	6	2	7	3	2	1										40
16-8-8 F_3					1	1	1	2	8	6	10	3	5	4	1	0	1									43
16-8-9 F_3					3	2	8	10	13	4	4															44
16-8-10 F_3				1	1	2	2	1	8	6	6	5	3	4	0	0	1									40
Bl. Mes. P_1							1	2	3	5	4	8	4	6	4	4	1	1								43
Gopher P_1					4	3	8	4	7	11	2	1														40
16-8-11 F_3						1	0	1	3	11	8	7	5	5	1	2										44
16-8-12 F_3						1	2	1	1	11	10	6	4	7	3	1	1									48
16-8-13 F_3				1	3	4	6	5	10	5	3	3														40
16-8-14 F_3			1	0	0	1	1	4	11	11	11	4	2	0	1											47
16-8-15 F_3			1	3	0	2	5	3	6	7	2	1	1													31
Bl. Mes. P_1					1	0	1	0	0	1	4	4	6	2	6	6	7	0	2							40
Gopher P_1						4	6	5	9	9	8	3	1													45
16-8-16 F_3		1	0	1	1	4	6	4	11	8	5	1	2													44
16-8-17 F_3							1	1	6	9	10	6	5	2	1	1										42
16-8-18 F_3						2	1	6	5	11	6	8	3	2												44
16-8-19 F_3							3	1	6	7	8	3	4	8	2	2										44
16-8-20 F_3				1	1	2	0	2	5	7	3	11	5	4	5	0	1									47
Bl. Mes. P_1									2	1	3	0	1	7	7	10	4	1								36
Gopher P_1					1	2	2	2	8	14	7	5	1													42
16-8-21 F_3				1	0	2	5	2	11	14	4	5	2													46
16-8-22 F_3			1	1	1	1	2	1	5	7	6	2	11	3												41
16-8-23 F_3									3	9	8	9	5	2	4	1										41
16-8-24 F_3		1	0	2	1	0	0	11	14	7	4	1	2													43
16-8-25 F_3						1	1	3	7	14	8	5	4	2	2											47
Bl. Mes. P_1						1	0	0	2	0	1	1	3	8	10	6	3	4								39
Gopher P_1					1	1	3	12	11	8	4	2														42

Bulletin 218

March, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. GIDDINGS, Acting Director
Morgantown

Effect of Winter Rations on Pasture Gains of Calves Marketed as Three-Year-Old Steers

Fig. 2.—Calves at Beginning of Experiment, December 22, 1922.

By
C. V. WILSON, R. H. TUCKWILLER,
and
E. W. SHEETS

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. ....President of the University
N. J. GIDDINGS, Ph. D. ....Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr., ...Agricultural Editor
JOHN C. JOHNSTON ....Chief Clerk

---

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.,
Assistant Animal Husbandman

J. H. Rietz, D. V. M
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va

Effect of Winter Rations on Gains of Calves Marketed as Three-Year-Old Steers

The work reported in this bulletin is part of a series of experiments on beef-production problems in the Appalachian Mountain region that has been in progress since December 22, 1924, in cooperation between the Bureau of Animal Industry of the United States Department of Agriculture and the West Virginia Agricultural Experiment Station, on the farm of David Tuckwiller, in Greenbrier County.* This farm is situated in the southeastern part of the state, in the bluegrass area. The results of this experiment apply not only to West Virginia, but also the adjacent states having similar conditions, as shown in Figure 1. Some of the methods and results may be utilized to advantage by cattle feeders in other parts of the country.

The topography of most of this region is mountainous. Practically all the region is suitable for grazing. There are a great many valleys and plateaus where the land varies from almost level to gently rolling. Such land is well adapted to pasture and the production of cultivated crops. Though the region for the most part is cleared of virgin forest, there are still large areas of cut-over land. The farms vary in size from less than 100 to more than 1,000 acres. On most farms there is sufficient tillable land for the production of winter feed. Relatively little surplus grain is produced.

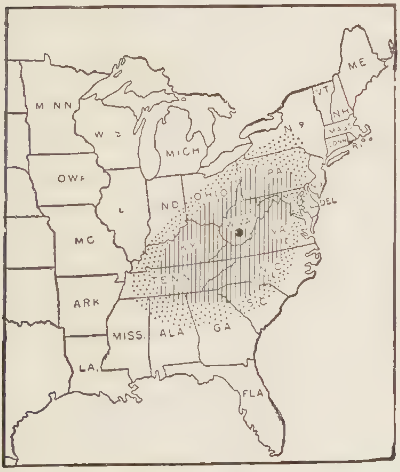


Fig. 1.—Map showing region to which this work applies. The black dot indicates the location of the farm on which the experiment was conducted. The shaded portion represents the area to which the results are applicable, and the dotted portion shows an additional area to which the results apply in part.

Most of the grass-fattened cattle which go annually to eastern markets are produced in this region. The fact that most of them are finished for market on grass alone attests the value of the pastures, which consist largely of bluegrass. The use of grain for finishing cattle is not

*The work of the Federal Department was under the direction of E. W. Sheets, Chief, Animal Husbandry Division, Bureau of Animal Industry.

One steer was struck by lightning on June 6, 1925, this being the only animal lost in the three years.

The outline in Table 1 shows how the steers were fed each winter until they were fattened on grass as three-year-olds. Only the feeds to be compared are put into the diagram. Corn silage and wheat straw were fed to every lot each winter, except Lot III in the first winter, which received mixed hay and a grain mixture.

TABLE 1.—Outline of Three Years' Winter Feeding.

1922-23		1923-24		1924-25	
Lot	Ration	Lot	Ration	Lot	Ration
I (30 calves)	Clover hay Corn silage Wheat straw	A (30 yearlings. 10 each from Lots I, II, and III of preceding winter)	Clover hay Corn silage Wheat straw	(90 head two-year-olds, Lots A, B, and C of preceding winter combined)	Cottonseed meal Corn silage Wheat straw
II (30 calves)	Cottonseed meal Corn silage Wheat straw	B (Same as A)	Cottonseed meal Corn silage Wheat straw		
III (30 calves)	Mixed hay Grain mixture*	C (Same as A)	Mixed hay Corn silage Wheat straw		

*Consisted of 3 parts, by weight, of corn, 1 of bran, and 1 of linseed meal.

QUANTITY OF FEED CONSUMED AND GAINS MADE

Table 2 shows the total quantity of the different feeds consumed by the various lots and the average daily ration per steer in each lot during each of the three winters. All lots were fed to gain in weight during the winter.

At the beginning of the second winter feeding period, December 17, 1923, three new lots were made by taking 10 steers from each of the three original lots, and these are hereafter designated as Lots A, B, and C. The purpose was to offset the effects of the rations fed the first winter and to make it possible to get a fair and direct comparison of rations fed the second winter. In order to study more in detail the effects of the winter ration on subsequent gains the second winter and thereafter, each 10 steers from the original Lots I, II, and III of the first winter were numbered A_1, A_2, A_3, B_1, B_2, B_3, and C_1, C_2, C_3. The letters designate each lot of 10 steers, and the numerals

TABLE 2.—Average Total and Daily Rations and Gains per Steer During the Three Winters. All Amounts Are Given in Pounds.

Winter of	Lot	Winter Feed	Total Feed per Steer	Daily Feed per Steer	Average Initial Weight per Steer	Average Weight per Steer at End of Winter	Total Gain per Steer
1922-23 (124 Days)	I	Clover hay	400.0	3.2	388	446	58
		Corn silage	1,528.5	12.3			
		Wheat straw	124.0	1.0			
	II	Cottonseed meal	92.2	.7	383	462	79
		Corn silage	1,528.5	12.3			
		Wheat straw	412.5	3.3			
	III	Mixed hay	1,240.0	10.0	389	502	113
		Grain mixture*	368.5	3.0			
1923-24 (120 Days)	A	Clover hay	603.0	5.0	575	662	87
		Corn silage	2,166.0	18.0			
		Wheat straw	242.0	2.0			
	B	Cottonseed meal	120.0	1.0	576	655	79
		Corn silage	2,166.0	18.0			
		Wheat straw	603.0	5.0			
	C	Mixed hay	603.0	5.0	575	615	40
		Corn silage	2,166.0	18.0			
		Wheat straw	242.0	2.0			
1924-25 (126 Days)	All three lots the same	Cottonseed meal	135.2	1.1	905	940	35
		Corn silage	3,272.0	26.0			
		Wheat straw	607.5	4.8			

*Consisted of 3 parts, by weight, of corn, 1 of bran, and 1 of linseed meal.

indicate the source from which they came. For example, the numeral 1 identifies the 10 head taken from the original Lot I. By referring to Table 2 it may be seen that Lot A was fed clover hay, corn silage, and wheat straw during the winter of 1923-24 (second winter), and that Lot I also received the same feeds the first winter. A_1, then, identifies 10 head of steers fed the first winter on clover hay, corn silage, and wheat straw, and the second winter on the same ration. C_3 designates the 10 head fed during the winter of 1923-24 on mixed hay, silage, and wheat straw, and the previous winter on mixed hay and grain mixture, and so on. The gains made by the steers on pasture during the summer periods are shown in Table 3.

Reference to Table 2 shows that during the first winter Lot I gained 58 pounds; Lot II, 79 pounds; and Lot III, 113 pounds. During the following summer (Table 3), Lot I gained 127 pounds; Lot II, 119 pounds; and Lot III, 99 pounds per steer.

TABLE 3.—Average Total and Daily Gain in Pounds per Steer on Pasture During the Three Summer Periods.

Years and Days on Pasture	Lots	Initial Weight, Beginning of Summer	Final Weight, End of Summer	Total Gain	Daily Gain
1923 (236 days)	I	446	573	127	6.54
	II	462	581	119	.50
	III	502	601	99	.42
1924 (241 days)	A	662	898	236	.98
	B	655	916	261	1.08
	C	615	900	285	1.18
1925 (141 days)	All combined	940	1,259	319	2.26

During the second winter Lot A gained 87 pounds; Lot B, 79 pounds; and Lot C, 40 pounds. In the second summer Lot A gained 236 pounds; Lot B, 261 pounds; and Lot C, 285 pounds.

These data show that when the cattle are turned on grass in the summer (without additional feed) the lots which gain heavily during the previous winter do not gain so much in the following summer, and that the lots gaining least in winter make relatively large summer gains.

COMPARISONS OF WINTER RATIONS

In order to make a more complete study of the effect of different winter rations from year to year on the grass-fat steers ultimately produced, Table 4 was prepared.

Since all 90 head were fed the same ration during the third winter, as noted before, Table 5 comparing the first two years is given.

Fig. 3.—Three-year-old Steers at Close of Experiment, on Arrival at Jersey City Market, September, 1925.

TABLE 4.—Average Weights of Steers at Beginning and End of Each Winter Period in Pounds.

Lots and Rations	December, 1922	April, 1923	December, 1923	April, 1924	December, 1924	April, 1925	September, 1925	Total Gain (988 Days)
A_1, 10 steers from Lot I, fed clover hay, silage, and straw first winter	385	442	555	652	874	900	1,200	815
A_2, 10 steers from Lot II, fed cottonseed meal, silage, and straw first winter	371	447	562	635	879	919	1,213	842
A_3, 10 steers from Lot III, fed mixed hay and grain mixture first winter	398	515	609	698	940	969	1,302	904
Lots $A_{1,2,3}$ fed clover hay, silage, and straw second winter								
B_1, 10 steers from Lot I fed as A_1	374	432	542	615	858	902	1,202	828
B_2, 10 steers from Lot II, fed as A_2	391	476	589	680	947	999	1,268	877
B_3, 10 steers from Lot III, fed as A_3	379	488	599	671	942	965	1,291	912
Lots $B_{1,2,3}$ fed cottonseed meal, silage, and straw second winter								
C_1, 10 steers from Lot I fed as A_1	404	465	592	632	927	960	1,307	903
C_2, 10 steers from Lot II fed as A_2	387	463	561	607	886	933	1,284	897
C_3, 10 steers from Lot III fed as A_3	390	502	572	608	891	919	1,259	869
Lots $C_{1,2,3}$ fed mixed hay, corn silage, and wheat straw second winter								

COST OF RATION

To figure the cost of wintering and summering the steers (Table 6) it becomes necessary to fix the prices for feeds used in the experiment. On account of fluctuations of the market, and also for simplicity in making the various calculations, an approximation of the local market feed prices per ton and pasture per day for the three years was used as follows:

Corn silage	$ 6.00
Cottonseed meal	50.00
Mixed hay	18.00
Clover hay	17.00
Wheat straw	7.00
Grain mixture*	39.76
Pasture per day:	
Yearlings	.03
2-year-olds	.05
3-year-olds	.10

The cost of the winter feed was considerably more than the cost of summer feed, yet the gain was made chiefly in summer.

ANALYSES OF FEEDS

The feeds used during the winter feeding in these experiments were analyzed by the West Virginia Agricultural Experiment Station. The analyses are shown in Table 7.

*Based on corn at 96 cents a bushel, wheat bran at $40 a ton, and linseed meal at $56 a ton.

TABLE 5.—Comparison of Winter and Summer Gains, in Pounds, First Two Years of Experiment.

Lot	First Year: Winter: Ration	First Year: Winter: Gain	First Year: Summer: Gain on Pasture	First Year: Total Gain	Second Year: Winter: Ration	Second Year: Winter: Gain	Second Year: Summer: Gain on Pasture	Second Year: Total Gain	Third Year: Total Winter and Summer Gain
A_1	Clover hay, silage, and straw	57	113	170	Clover hay, silage, and straw	97	222	319	326
A_2	Cottonseed meal, silage, and straw	76	115	191	do	73	244	317	334
A_3	Mixed hay and grain mixture	117	94	211	do	89	242	331	362
B_1	Clover hay, silage, and straw	58	110	168	Cottonseed meal, silage, and straw	73	243	316	344
B_2	Cottonseed meal, silage, and straw	85	113	198	do	91	267	358	321
B_3	Mixed hay and grain mixture	109	111	220	do	72	271	343	349
C_1	Clover hay, silage, and straw	61	127	188	Mixed hay, silage and straw	40	295	335	380
C_2	Cottonseed meal, silage, and straw	76	98	174	do	46	279	325	398
C_3	Mixed hay and grain mixture	112	70	182	do	36	283	319	368

Groups A_1, B_1, and C_1 were fed as Lot I the first winter.
Groups A_2, B_2, and C_2 were fed as Lot II the first winter.
Groups A_3, B_3, and C_3 were fed as Lot III the first winter.
During the second winter all A groups constituted Lot I, B groups Lot II, and C groups Lot III.

TABLE 6.—Cost per Steer of Winter Feed and Summer Pasture, and Cost per Pound of Total Gain.

Lots	Total Gain per Steer, Three Years in Pounds	Cost of Feed per Steer: Winter 1922-23	Summer 1923	Winter 1923-24	Summer 1924	Winter 1924-25	Summer 1925	Total	Cost of Feed per Pound of Gain in Cents
A_1	815	$ 8.42	$7.08	$12.48	$12.05	$15.33	$14.10	$69.46	8.5
A_2	842	8.34	7.08	12.48	12.05	15.33	14.10	69.38	8.2
A_3	904	18.49	7.08	12.48	12.05	15.33	14.10	79.53	8.8
B_1	828	8.42	7.08	11.61	12.05	15.33	14.10	68.59	8.3
B_2	877	8.34	7.08	11.61	12.05	15.33	14.10	68.51	7.8
B_3	912	18.49	7.08	11.61	12.05	15.33	14.10	78.66	8.6
C_1	903	8.42	7.08	12.78	12.05	15.33	14.10	69.76	7.7
C_2	897	8.34	7.08	12.78	12.05	15.33	14.10	69.68	7.8
C_3	869	18.49	7.08	12.78	12.05	15.33	14.10	79.83	9.2

TABLE 7.—Analyses of Feeds, Reported in Percentages.

Feed	Year	Water	Ash	Protein	Fiber	Nitrogen-Free Extract	Fat
Silage	1922-23	64.07	1.06	2.64	5.92	24.87	1.44
	1923-24	60.50	3.15	3.06	7.43	24.37	1.49
Clover hay	1922-23	5.60	4.77	8.81	40.70	38.32	1.80
	1923-24	6.34	5.20	9.61	34.14	42.55	2.16
Mixed hay	1922-23	5.90	4.96	8.64	35.54	42.75	2.21
	1923-24	5.10	4.04	6.14	31.51	50.58	2.63
Wheat straw	1922-23	4.87	4.03	4.48	41.66	43.68	1.28
	1923-24	5.08	3.49	4.08	42.27	43.44	1.64
Corn	1922-23	8.60	1.23	9.98	2.58	73.20	4.41
Linseed meal	1922-23	7.93	4.86	35.76	8.22	36.11	7.12
Cottonseed meal	1922-23	8.44	5.94	34.28	12.95	32.02	6.37
	1923-24	8.14	6.56	36.46	11.42	30.78	6.64
Bran	1922-23	7.91	6.60	15.76	10.61	53.64	5.48

CONCLUSIONS

From a study of the growth curves shown in Figures 4 and 5 it may be seen that a loss in weight during the last two months of the grazing periods occurred both in 1923 and 1924. In other words, the average weight of the 90 steers on October 10, 1923, was practically the same as it was six months later, or April 18, 1924. This suggests a point worthy of more study and investigation. This loss of weight after frost comes in the fall and before putting the cattle into winter quarters should undoubtedly be avoided. The solution may lie either in supplementing this late fall pasture with grain or in placing the cattle into winter quarters earlier.

As a rule the lots of calves and yearlings which made the least winter gains made the greatest summer gains, and conversely the lots gaining most in winter gained least in summer on pasture.

Differences in gains made by calves and yearlings during the winters, 1922-23 and 1923-24 brought about by the rations fed were minimized during the summers of 1923 and 1924 when they were on pasture.

There were relatively little differences between the average annual gains of the different lots of calves and yearlings at the end of the first and second summer grazing periods. When these lots of calves and yearlings were then fed the same winter ration as two-year-old steers and finished on pasture as three-year-old steers all lots sold in Jersey City at the same price per pound. Therefore, the cost of wintering rations, fed in this experiment, is of relatively greater importance than the kind of ration when fed to calves and yearlings that are to be finished on pasture as three-year-old steers.

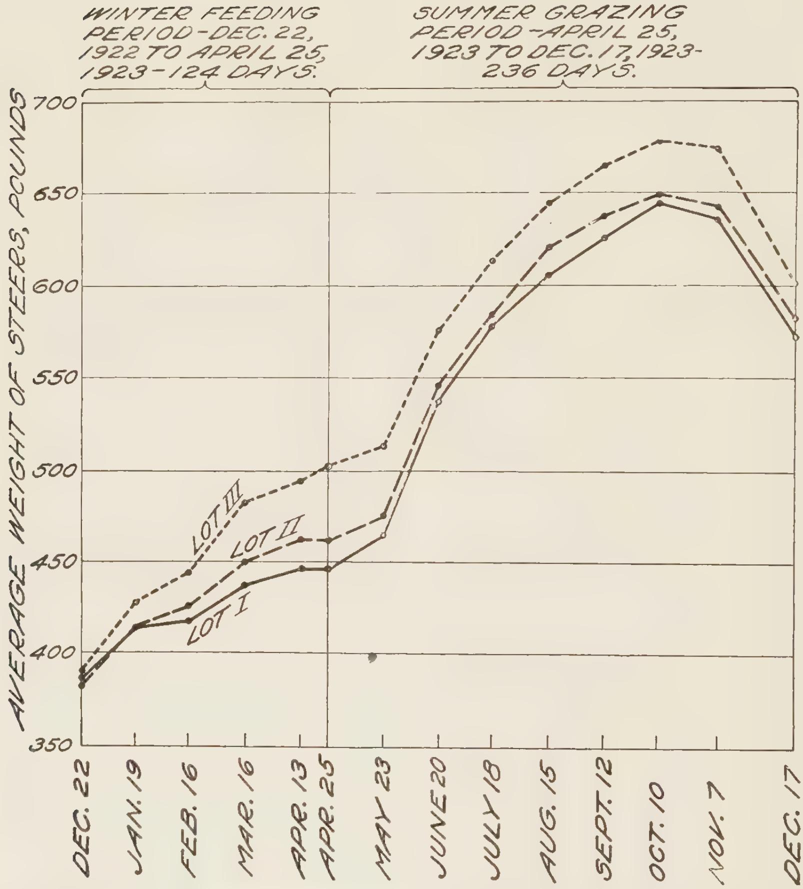


Fig. 4.—Gains of Steers During Winter and Summer, December 22, 1922, to December 17, 1923.

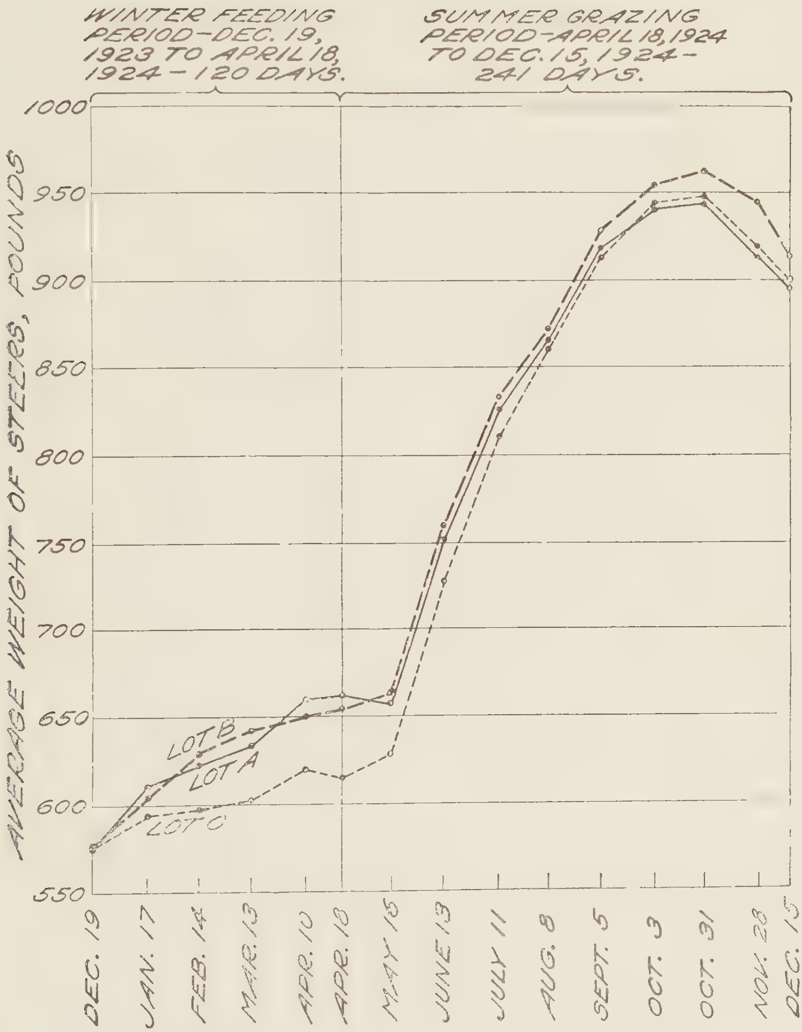


Fig. 5.—Gains of Steers During Winter and Summer, December 19, 1923, to December 15, 1924.

FERRETED FACTS

Fourteen years (1914-28) of experimental investigations as to feeding of beef cattle on the Tuckwiller Farm show conclusively:

1.—That the cost of winter feeding is the most important factor in the economy of beef production for the area represented by this work. (See Figure 1.)

2.—That the use of corn silage will lower the cost of winter feeding and when fed along with the ordinary farm roughages will enable the farmer to feed more cattle for a longer period than he can on the same feed if fed in a dry state alone.

3.—That corn silage with a good leguminous roughage makes a satisfactory and economical wintering ration for cattle of any age including breeding cows.

4.—That winter gains exceeding 75 pounds on three-year-old steers are excessive unless the cattle are extremely thin when placed in winter quarters, or it is desired to market them as early as July.

You Are Invited

Farmers who live in the Greenbrier Valley section or whose business or pleasure brings them within proximity of Lewisburg are cordially invited to visit the Tuckwiller Farm and see at first hand the cooperative experimental work that is being conducted there with beef cattle.

A three-year experiment with three-year-old steers has just been completed, in which two grades of steers, good and medium, were compared, and grass alone for summer feeding contrasted with grass supplemented by grain. Results of this work are being prepared and will be published at an early date.

Starting in the fall of 1928 further work with grain feeding will be continued for a three-year period. Younger cattle will be used and a study of the time at which to begin grain feeding on grass will be made.

The Tuckwiller Farm is readily accessible at all seasons of the year being located on the Midland Trail 4 miles west of Lewisburg and 106 miles east of Charleston. It is suggested that a visit to the farm would make a good tour or vacation trip for a group of farmers who might arrange to make the trip together. Any group desiring to visit the farms and see this experimental work may obtain information as to the times at which winter feeding will begin and end, summer feeding begin, and final summer weights be taken, by writing to the Animal Husbandry Department of the West Virginia Agricultural Experiment Station at Morgantown.

Beef Cattle In West Virginia

The raising of beef cattle has a very definite place on many West Virginia farms as an important farm enterprise. The profitableness of the enterprise, however, depends upon how well the farmer understands the fundamental principles of feeding, care, and management and is able to apply them.

The West Virginia College of Agriculture is striving through the work on its Experiment Station to discover facts about the raising of beef cattle that will be of help to the farmers in the state in making the enterprise more successful and profitable.

These facts are disseminated in three major ways: (1) By the teaching staff of the College through resident instruction to students; (2) Through the work of Extension Division and its field representatives—the livestock specialists and county agricultural agents; and (3) Through the means of publications which are distributed free to those interested.

If you have any special problems, in handling your beef cattle, consult your county agricultural agent, or write to the College for suggestions and aid. One of the following publications of the Experiment Station may contain the information you need:

Bul. 186, Effect of Winter Rations on Pasture Gains of Beef Calves and Yearlings.

Bul. 190, Feeding Experiments With Grade Beef Cows.

Bul. 191, Effect of Winter Rations on Pasture Gains of Two-Year-Old Steers.

Cir. 40, A brief extract of bulletin 191 (8 pages).

Bulletins and circulars on other farm problems are also available for distribution. A complete list of available publications will be issued about January 1, 1929. Write for it. Address your request to

COLLEGE OF AGRICULTURE

West Virginia University **Morgantown, W. Va.**

Bulletin 219

May, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. GIDDINGS, Acting Director
Morgantown

The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

(Technical)

By

T. E. ODLAND

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr., ... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.,
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

CONTENTS

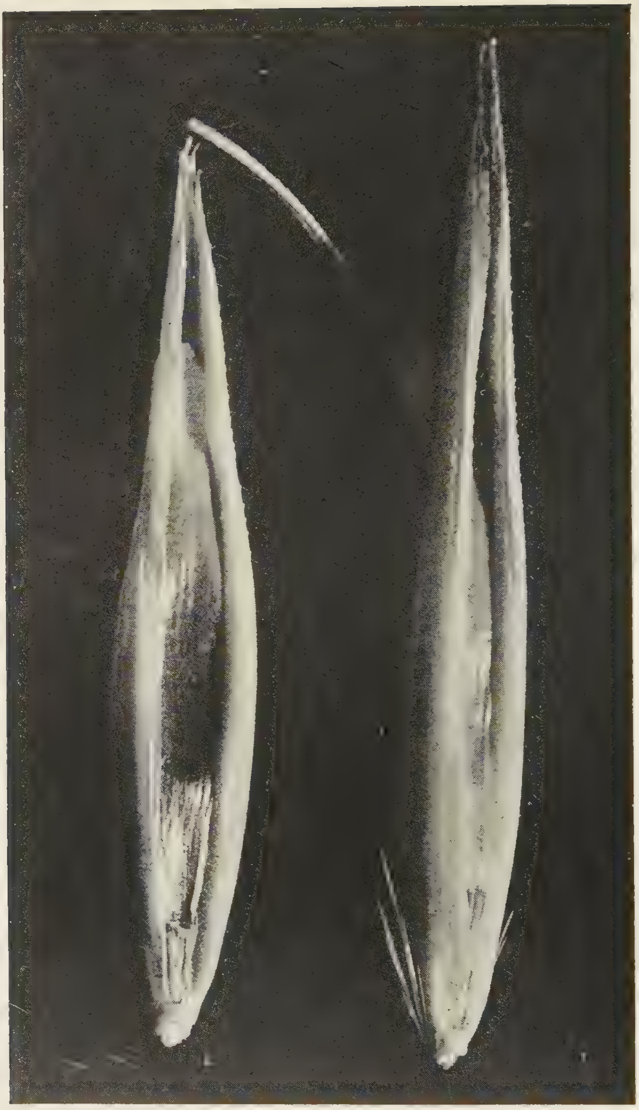


Fig. 1.—Grain types of the parental varieties. Garton 784 on left and Early Gothland on right.

The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

The inheritance of quantitative characters such as yield, size of plant, and others of like nature has been much less extensively studied than the inheritance of qualitative characters. The reason is found largely in the fact that they are usually much less easily analyzed and often present rather complex problems. Quantitative characters are often so influenced by environmental conditions that genetic differences are obscured. A number of workers have, however, demonstrated that the inheritance of size characters may be explained on a factorial basis similar to that of the inheritance of qualitative characters. Sax *(16)*, Lindstrom *(9)* and others have pointed out the desirability of attempting to correlate size characters with easily recognized qualitative characters and thus facilitate the analysis of the former in any inheritance study.

A quantitative character that is relatively stable under varying environmental conditions is obviously very desirable for making a study of the nature of size inheritance. In the present study the size character chosen, length of rachilla in oats, seemed to offer an exceptionally stable character and one that could be studied in relation to a number of definite qualitative characters.

REVIEW OF LITERATURE

East *(2)* made a study of the inheritance of corolla length in a tobacco cross. This study is taken as typical of many size inheritance studies made by East. In this tobacco cross the corolla length in the F_1 generation was intermediate between the two parents and was only slightly more variable than the more variable parent. The F_2 generation ranged between the two parents and had a much greater variability than either the parents or the F_1 generation. In the F_3 and succeeding generations families were recovered with various lengths of corolla. Some of these families showed a variability no greater than that of the parents, while others were more like the F_2 in this respect. The data indicate that the inheritance of this character can

---

*Presented to the faculty of the Graduate School of Cornell University, Ithaca, N. Y., June, 1926, as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Submitted for publication as a Station Bulletin, October, 1926.

Acknowledgement is due to Dr. H. H. Love, of Cornell University, for his helpful direction and guidance during the course of this investigation, and to Dr. R. J. Garber, of West Virginia University, who contributed many valuable suggestions with respect to outlining the problem and handling the data.

be explained on a multiple factor basis. In this paper East outlines certain requirements which, if met in a size inheritance study, tend to indicate that the results may be explained on a factorial basis.

Quisenberry *(15)* in a study of the inheritance of length of grain in an oat cross found the F_1 to have grains intermediate in length while the F_2 ranged from one parent to the other. In 150 F_3 families, two were recovered with a mean length as short as the short parent and four with a length as great as the long parent. Between the extremes were lines that apparently bred true for intermediate lengths. The results were explained on the basis that the parents differed by at least three main factors or groups of factors for grain length.

Garber and Quisenberry *(6)* studied the inheritance of date of heading, leaf width, number of culms, and color of seed in another oat cross. Earliness was found to be inherited as a dominant character with evidence of a two factor difference. Leaf width was found to be a variable character. One F_3 family was recovered with a leaf width less than the narrow-leaved parent. The data indicated that this character was controlled by multiple factors. The number of culms was also found to be greatly influenced by environment, but the data indicated that it was an inherited character. Seed color was found to be due to a single factor difference. No evidence of linkage was found between any of the characters studied.

Noll *(14)*, in a study of the inheritance of earliness in crosses between early and late varieties of oats, found the F_1 generation to be as early or earlier than the early parent. The F_2 ranged beyond the extremes of both parents. Homozygous races were obtained in F_3 and F_4 which covered the same range as the F_2. Earliness was apparently due to a series of dominant factors, which together had a cumulative effect. The data, the author states, indicate but do not prove conclusively that the factors had the same effect.

Caporn *(1)* crossed an early with a late variety of oats. Two lines out of 106 F_3 families were found to be as early as the early parent but no lines were recovered that were as late as the late parent. The author explains the results obtained on a three factor basis. Late ripening was found to be closely associated with the amount of tillering.

Nilsson-Ehle *(12)* made a study of various size characters. These studies have been reviewed by Hayes and Garber *(8)*. Transgressive segregation was found in oat crosses involving differences in height, leaf width, kernel size, and number of florets per spikelet. The results were explained on a multiple factor hypothesis. Nilsson-Ehle also

obtained transgressive segregation for date of maturity in certain oat crosses. Homozygous forms were obtained in the F_3 progenies which were earlier than the early parent and also some that were later than the late parent.

The linkage of size factors with certain qualitative characters have been noted by several workers. Tedin and Tedin *(18)* crossed a two-rowed hulled with a six-rowed hull-less barley. The two-rowed barley was about ten centimeters higher than the other variety. The inheritance of type of spike and of the hull condition was explained on single factor differences which were independent of each other. Evidence for linkage between the factor for two-rowedness and a factor for plant height was found. The authors state that evidence was also found that heterozygosity in the factor for two-rowedness had a marked "stimulating" effect upon height of plant.

Sax *(16)* studied the relation between size of seed and pigmentation of seed in beans. A linkage was found between factors, or groups of factors, for seed weight and factors for pigmentation and pattern of the seed coat.

Lindstrom *(9)* in a study of inheritance of size of tomatoes found that a factor for size of fruit was linked with a factor for skin color.

Griffe *(7)* using barley, studied the relation of resistance to *Helminthosporium sativum* and certain morphological characters. He concluded that resistance to this disease was controlled by at least three factors or groups of factors apparently linked with the factors determining the character pairs: six-rowed versus two-rowed; black versus white glumes, and rough versus smooth awn. The linkage was not complete as resistance or susceptibility could be combined with any desired morphological character.

MATERIALS AND METHODS

The object of the study reported in this bulletin was to attempt to determine the mode of inheritance of a definite size character, length of rachilla in oats, and its relation to certain other qualitative characters. The material for this study was obtained by making a cross between Early Gothland *(Avena sativa)* and Garton 784 *(Avena sativa orientalis)*.

The Early Gothland parent has a pubescent rachilla approximately 2.7 millimeters long on its lower grain (Fig. 1), while in the Garton 784 parent the rachilla is extremely short, being only approximately 1.6 millimeters long. It is free from pubescence except for an occasional hair.

Early Gothland is a white grained variety, has an open type of panicle (Fig. 2), and has a leaf with a very prominent ligule. The Garton 784 parent has black colored grains, haş a side type of panicle, and has no ligule at the juncture of the leaf blade and the leaf sheath. The parental material used all descended from a single panicle of each variety selected from pure line material grown in the Plant Breeding Nursery at Morgantown, West Virginia, in 1921. The reciprocal crosses were made in 1922.

Figure 2.—Panicle types of the parental varieties. Early Gothland on left and Garton 784 on right.

An F_1 generation was grown in the greenhouse during the winter 1922-23. The plants were late in maturing so that only enough seeds were secured to grow an F_2 population of 290 plants in 1923. A few additional F_1 plants and also parental material were grown with the F_2 generation in the field. Larger F_2 populations were grown in 1924 and 1925. A few F_1 plants and also parental material were grown with these each year. In 1925 F_3 families were grown from a number of the F_2 plants.

All material in this study was grown in rows five feet long and spaced one foot apart. Twenty seeds were planted per row. At the end of each row and set off by a small stake, three seeds of Victory oats were planted in order to eliminate border effect as far as possible. These plants were pulled and discarded before any of the plants under study were harvested. When it was necessary to plant only a part of a row of the material under study on account of lack of seed, the remainder of the row was planted to Victory and the plants discarded in the same manner as the border plants.

The F_3 families from which it was planned to get rachilla measurements were all planted in five-row plots except in a few instances where there was not enough seed. Rachilla measurements were made on 60 such F_3 families. In addition to these, 75 families consisting of only one row each were grown in order to get additional data on the relation of the ligule and panicle type. The five-row F_3 families were all from F_2 plants grown in 1924 while the single row families were from both the 1923 and 1924 F_2 plants. The parental material in 1925 was grown in 18 three-row plots distributed among the F_2 and the F_3 families. Both parents appeared at distances of from 23 to 36 rows apart. The average distance apart of the parental material was 30 rows.

A plot of each variety was also grown on rich and poor soil in 1923 for the purpose of studying the influence of the productivity of the soil on the length of the rachilla.

The rachilla measurements were made by means of a pair of proportional dividers (Fig. 3) using a ratio of 10 to 1 and reading the measurements on a millimeter scale. The units in which the measurements are reported are in terms of .1 millimeters. A mounted reading glass was used to facilitate making the readings obtained with the dividers.

The classification of the panicle type and the ligule note were made in the field before the plants were harvsted. The classifications for color of grain and for rachilla pubescence were made at the time that the rachilla was measured.

DETERMINATION OF SIZE OF SAMPLE

Before proceeding with the measuring of the F_2 material it was necessary to make measurements of the rachillas of the parental material in order to determine how many grains would be necessary for a dependable sample from each plant. Preliminary measurements made in 1922 had shown that the length of rachilla did not vary significantly on grains taken from the base to tip on the same panicle nor on grains from different panicles of the same plant. The leading panicle was therefore chosen to represent each plant measured. The grains selected from this panicle were taken in a systematic order from the tip to the base of the panicle..

The preliminary measurements also indicated that the short rachilla parent was probably the more variable as measured by the coefficient of variability. This parent was therefore chosen for making a determination on the size of sample required to represent a plant. For this study 15 grains were taken in systematic order from tip to base of the leading panicle from 100 Garton 784 plants grown in 1923. Samples consisting of three, five, and eight grains from each panicle were then made up from the original 15-grain samples. Frequency distributions were then made of the means as secured by these different samples. The statistical constants obtained are shown in Table 1.

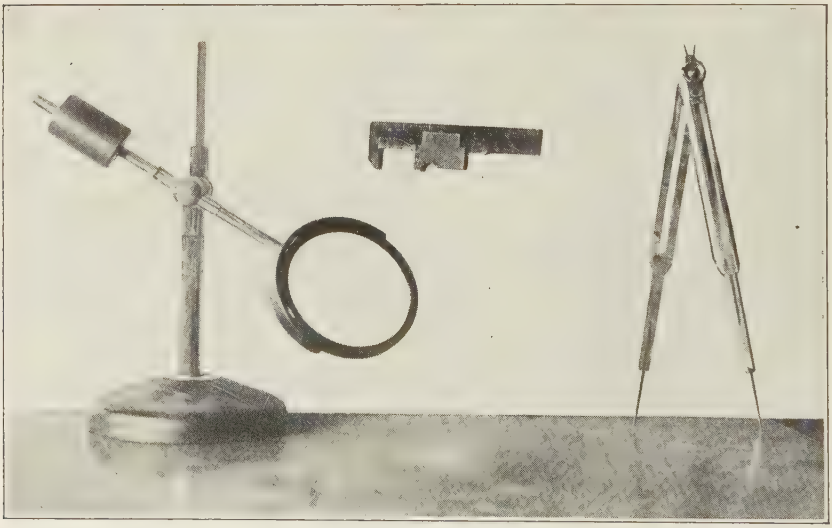


Fig. 3.—Equipment used in making rachilla measurements.

TABLE 1.—Statistical constants for length of rachilla for samples of 3, 5, 8, and 15 grains obtained from 100 plants of the Garton 784 parent grown in 1923.

Number of Grains in Sample	Number of Samples	Means in .1 mm. Units	Standard Deviation	Coefficient of Variability	E_s
3	100	16.570±0.070	1.042±0.050	6.29±0.30	0.703
5	100	16.630±0.065	0.966±0.046	5.81±0.28	0.652
8	100	16.570±0.057	0.852±0.040	5.14±0.24	0.575
15	100	16.510±0.054	0.806±0.038	4.88±0.23	0.544

The data of Table 1 show that there is no significant difference in the means for length of rachilla, whether three, five, eight, or fifteen grains were selected as a representative sample. The standard deviation and the coefficient of variability are reduced as the size of sample is increased. It was decided to use a sample of five grains from each plant as a representative sample for determining the length of rachilla.

DETERMINING THE SIZE OF F_3 FAMILIES

The question also arose as to how many plants it would be necessary to grow in order to obtain a dependable estimate of the breeding behavior for the length of rachilla in any particular family in the F_3 and later generations. This question was of considerable importance in this study on account of the amount of time it required to make the measurements.

For this study the F_2 population grown in 1923 was used. The 290 F_2 plants were first divided into 10 samples of 29 plants each by selecting plants 1, 29, 58, and so on, for sample number one, plants 2, 30, 59, and so on, for sample number two, and proceeding in the same way for the other eight samples. In a similar way six samples of 48 plants each, five samples of 58 plants, and three samples of 96 plants were made up. Statistical constants were then calculated for each of these samples. These constants are given in Table 19 of the appendix. In Table 2 a summary is given of the results obtained.

Since the coefficient of variability is the constant which is frequently used to determine if any F_3 family is homozygous for any given set of size factors, a comparison of this constant in the various samples will give an indication of the number of individuals which

TABLE 2.—Range in means and in coefficients of variability for length of rachilla when samples of 29, 48, 58, and 96 plants were taken from the F_2 generation grown in 1923.

Number of F_2 Plants in Sample	Number of Samples	Range in Means		Range in Coefficients of Variability	
		High	Low	High	Low
29	10	22.172±0.289	21.207±0.295	12.29±1.10	8.00±0.71
48	6	21.917±0.214	20.937±0.215	11.27±0.79	8.91±0.61
58	5	21.690±0.211	21.362±0.174	11.24±0.71	9.19±0.57
96	3	21.875±0.161	21.000±0.142	10.66±0.53	9.48±0.46
290	1	21.652±0.083		9.65±0.27	

will be required to give a trustworthy sample of the F_2 generation. Since no F_3 families with a variability greater than that of the F_2 are ordinarily expected in any cross of this kind involving size factors, any sample that is found satisfactory as a representative of the F_2 population should be large enough to be taken as a trustworthy sample of any of the F_3 and later progenies grown.

Table 2 shows the coefficient of variability ranges from 8.00± 0.71 to 12.29±1.10 when samples of only 29 individuals were taken. The wide range in this constant indicates that this would not be a sample large enough to fairly represent the entire F_2 population. When 48 plants were used the coefficient ranges from 8.91±0.61 to 11.27±0.79. The coefficient of variability for the entire population is 9.65±0.27. As the number of individuals in the samples is increased to 58 and 96 respectively the range between the high and low coefficients becomes less. From these data it would seem that about 50 individuals in the F_3 families could be accepted as being a trustworthy sample. On account of the other characters studied in connection with the size character it was decided to plant 100 seeds for each F_3 family where enough seed was available but to measure only a random sample of 50 plants taken from each family.

EFFECT OF SOIL PRODUCTIVITY ON LENGTH OF RACHILLA

In order to study the effect of the productivity of the soil on the length of rachilla a plot of each parent was planted on both rich and poor soil. The rich soil plots were located on land that had at one time been used for gardening purposes and which had received heavy applications of fertilizers and manure. The plots located on the poor

soil were located on a ridge where the soil was in a very low state of productivity. The plots consisted of 15 five-foot rows each.

The heights of all plants were taken before harvest. Each plant was harvested and threshed separately. The grains for measuring were removed from the leading panicle before threshing. One hundred plants taken in order from each plot were used for rachilla length determinations. In tabulating the data obtained, only the yields and heights from the plants on which rachilla measurements were made have been used. A summary of the results obtained is given in Table 3.

TABLE 3.—Means for length of rachilla, yield, and height of individual plants of Early Gothland and Garton 784 parents grown on rich and poor soil in 1923.

Parent	Number of Plants	Kind of Soil	Average Length of Rachilla in .1 mm. Units	Average Yield in Grams	Height in Centimeters
Early Gothland	100	Rich	27.720±0.067	6.95±0.25	114.70±0.55
Early Gothland	100	Poor	25.850±0.076	2.69±0.10	76.05±0.52
Garton 784	100	Rich	16.710±0.055	6.32±0.21	105.15±0.62
Garton 784	100	Poor	16.120±0.053	3.87±0.14	80.35±0.49

It is clearly evident from the results shown in Table 3 that there was a considerable difference in the productivity of the soil between the two plots both as measured by yield and by the height of the plants. The difference between the two plots of Garton 784 was relatively less in both instances than between the plots of Early Gothland.

It is also evident that the productivity of the soil has influenced the length of rachilla in both parents. In the Early Gothland parent the difference between the length of rachilla in the rich and poor soil plots amounts to 1.870±0.101 units and in Garton 784 it is 0.590± 0.076 units. Even with soil differences as extreme as these were, the differences in rachilla length were not large. Evidently this character is very stable and only relatively little influenced by soil differences.

INHERITANCE OF LENGTH OF RACHILLA

The mode or inheritance of length of rachilla was studied by making measurements of the hybrid material as described previously, computing statistical constants, and analyzing the data from a bio-

metrical standpoint. In this cross no significant difference was found between the reciprocal crosses in the inheritance of length of rachilla or in any of the other characters studied. In the tabulations and other data presented the two crosses are, therefore, combined.

A summary of the results obtained in the three years for measurements of the parental material, the F_1 plants, and the F_2 populations is given in Table 4. The data show that the length of rachilla varied only slightly in the different years both in the parents and in the F_2 populations. The means for the Early Gothland parent were 27.512 ± 0.060, 26.608 ± 0.054, and 26.885 ± 0.019 units for the three years 1923, 1924, and 1925, respectively. Between the years 1923 and 1924 there was a difference of 0.904 ± 0.081. This is a relatively small difference but significant in the light of its probable error. The difference between the means of this parent for 1924 and 1925 was 0.277 ± 0.057. The difference is about five times its probable error and indicates that there was less difference in seasonal influences between 1924 and 1925 than between 1923 and 1924. When the means for the years 1923 and 1925 are compared there is found to be a difference of 0.629 ± 0.063. This difference may also be considered as significant.

The coefficients of variability for this parent were 5.52 ± 0.15, 5.69 ± 0.14, and 3.18 ± 0.05 for the three years, respectively. It is obvious that there was no difference in variability in this parent as measured by the coefficient of variability between the years 1923 and 1924. The difference in this constant, however, between the two years 1923 and 1925, 2.34 ± 0.16, shows that this parent was less variable in 1925 than in the other two years. As will be shown later this was also true of the Garton 784 parent.

The means for the Garton 784 parent were 16.731 ± 0.040, 16.119 ± 0.034, and 16.210 ± 0.016 for the three years, respectively. The difference in means for the years 1923 and 1924 was 0.612 ± 0.052 units. This is not a large difference, but is significant in the light of its probable error. The difference in means for this parent between the years 1924 and 1925 was 0.091 ± 0.037, a difference less than three times its probable error and, therefore, not considered significant. The difference in means for the years 1923 and 1925 was 0.521 ± 0.043, which may be considered as a significant difference.

The coefficients of variability for this parent for the three years were 5.89 ± 0.17, 5.38 ± 0.15, and 4.37 ± 0.07, respectively. Between the years 1923 and 1924 there was a difference of 0.51 ± 0.23. This difference is not significant in the light of its probable error and,

TABLE 4.—Statistical constants for length or rachilla of the parents, F_1 and F_2 of the cross Early Gothland by Garton 784 and reciprocal.

Material or Generation	Year	Classes for Length of Rachilla in Units of .1 mm.																				Total No.	Means	Standard Deviation	Coefficient of Variability
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33				
E. G.	1923											4	15	61	72	74	42	16	8	2	1	295	27.512±0.060	1.518±0.042	5.52±0.15
E. G.	1924										6	19	58	88	82	61	32	3	2	1		352	26.608±0.054	1.513±0.038	5.69±0.14
E. G.	1925												45	223	422	173	18	1				882	26.885±0.019	0.855±0.014	3.18±0.05
G. 784	1923		14	114	88	36	14	2														268	16.731±0.040	0.986±0.029	5.89±0.17
G. 784	1924	1	67	152	63	16	2	1														302	16.119±0.034	0.868±0.024	5.38±0.15
G. 784	1925	1	117	497	253	24	2															894	16.210±0.016	0.708±0.011	4.37±0.07
F_1	1923						1	4	2													7	20.143		
F_1	1924							2	5	1	1											9	21.111		
F_1	1925						1	3	2	1												7	20.429		
F_2	1923			2	3	16	25	49	62	42	35	27	18	6	4	0	0	1				290	21.548±0.087	2.191±0.061	10.17±0.29
F_2	1924			4	12	32	71	86	99	92	54	43	24	8	3	1						529	21.185±0.062	2.116±0.044	9.99±0.21
F_2	1925			2	7	19	57	97	93	87	47	16	8	0	3							436	20.938±0.056	1.734±0.040	8.28±0.19

therefore, this parent is like the Early Gothland in that there was no difference in variability in the first two years of the experiment. Between the years 1924 and 1925 there was a difference of 1.01 ± 0.16, which is significant. The difference for this constant between the years 1923 and 1925 was 1.52 ± 0.18, which may also be considered as an actual difference. Like the Early Gothland parent the Garton 784 parent showed less variability in 1925 than in the other two years.

By means of the coefficient of variability the variability of the two parents may be compared directly. These constants did not differ significantly between the two parents in 1923 and 1924 but in 1925 there was a difference of 1.19 ± 0.09. This shows that in the latter year the Early Gothland parent was less variable than the other parent.

The means for the F_2 populations were 21.548 ± 0.087, 21.185 ± 0.062, and 20.938 ± 0.056 units for the three years 1923, 1924, and 1925, respectively. The difference in means between the years 1923 and 1924 was 0.363 ± 0.107 and between the years 1923 and 1925 it was 0.610 ± 0.103. The difference is approximately three times its probable error in the former case and six times its probable error in the latter case and, therefore, both are considered significant. The difference in means between the years 1924 and 1925 was 0.247 ± 0.084, a difference which is a little less than three times its probable error. The F_2 population, therefore, is like the parents in that the mean length of rachilla in the years 1924 and 1925 was slightly less than in 1923.

An examination of Table 4 shows that in variability, as measured by the coefficient of variability, there was no difference in the F_2 generation for the character under study between the years 1923 and 1924. Between the years 1924 and 1925 there was a difference of 1.71 ± 0.28, which is significant. In respect to variability, therefore, the F_2 showed less range in 1925 than in the previous years and was similar to the parents in this respect.

In all three years the F_1 plants showed a rachilla length which was approximately intermediate between the parents. The F_2 population ranged between the two parents although in no year were plants obtained with rachillas reaching the extremes of the parents.

The variation in length of rachilla from parent to parent in the F_2, with the mean of the population approximately midway between them and also a gradual falling off in numbers in the classes from the mid point to the two extremes, suggests that the inheritance of the length of rachilla can probably be best explained on a multiple factor basis.

If the factors concerned in the inheritance of this character were of equal value and had a cumulative effect, a normal frequency curve would be expected in plotting any F_2 distribution. As may be seen from Table 4, the type of curve obtained in plotting the F_2 distributions obtained in any year shows a considerable variation from a normal frequency curve. Skew curves such as the ones obtained suggest that the factors involved are either of unequal value in determining the length of rachilla or are modified by factors of unequal value.

BREEDING BEHAVIOR OF F_3 PROGENIES FOR LENGTH OF RACHILLA

Sixty-one F_2 plants from the 1924 F_2 generation were grown in F_3 families in order to test their breeding behavior for the inheritance of the length of rachilla. One of these families, 18-2-48 row 290, produced only seven plants. No measurements were made on these plants due to the lack of sufficient numbers. In subsequent tables this family is left out of consideration thus leaving 60 families on which measurements for length of rachilla were obtained. The F_2 plant from which this family was grown was continued in F_3, even if there were only a few seeds available because it seemed to be a False Wild oat plant. This proved to be the case as shown by its behavior in the F_3.

In four other F_3 families, 18-4-77, 18-5-31, 19-1-65, and 19-4-27 the number of plants matured were 45, 43, 38, and 15, respectively. The small number of plants in these families was due to lack of seed. In all other cases 50 plants were used for making length of rachilla determinations. The data obtained in measuring the length of rachilla of the F_3 families and of the parental material grown with these are shown in tables 20, 21, and 22 of the appendix.

In choosing the F_2 plants for continuing in the F_3, a number from each class for length of rachilla were chosen. The number from each class was approximately in proportion to the total number in that class in the entire F_2 population, except that nearly all the plants in the extreme classes were included. The plants were also chosen so that they would afford a test for the breeding behavior of the other characters studied.

A comparison of the distribution of the entire F_2 population and of the F_2 plants selected for continuing in the F_3 is shown in Table 5.

A distribution was obtained which represented the F_2 population fairly well, except for the extreme classes where proportionally more plants were included than in the intermediate classes. If the inheritance of length of rachilla is explained on a multiple factor basis, it

TABLE 5.—Comparison of the total number of F_2 plants, grown in 1924, in various classes for length of rachilla and the number from each class continued in F_3 progenies.

Plant Designations	Classes for Length of Rachilla in Units of .1 mm.						
	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Total No. F_2 plants . .	4	44	157	191	97	32	4
F_2 plants tested in F_3	4	6	12	19	9	7	3

would be expected that there would be a greater probability of the extremes breeding true for a certain length of rachilla than any of the intermediate classes. For this reason more of the extreme classes were included.

CORRELATION BETWEEN F_2 PLANTS AND THEIR F_3 PROGENIES

In order to determine to what degree the length of rachilla is inherited, a correlation coefficient was calculated for the means of the F_2 plants continued in the F_3 and the means of these F_3 families. The distributions are shown in Figure 4.

Length of Rachilla in F_2	Mean Length of Rachilla in F_3										Total
	17	18	19	20	21	22	23	24	25	26	
16	2	2									4
17		1	2								3
18		2	1								3
19		2	1	1	2						6
20				1	4	1					6
21				5	3	1	1				10
22				1	4	4					9
23						2	1	1			4
24						4	1				5
25						1		2			3
26							1	1	1	1	4
27						1		1			2
28										1	1
Total	2	7	4	8	13	14	4	5	1	2	60

$$r = 0.886 \pm 0.019$$

Fig. 4.—Correlation between average length of rachilla in F_2 plants and the mean length of rachilla in their F_3 progenies.

The coefficient obtained, $r = 0.886 \pm 0.019$, indicates that length of rachilla is an exceptionally stable size character, and that the F_2 gives a good indication of what may be expected in the F_3 progeny from any plant.

VARIABILITY IN F_3 PROGENIES

The coefficient of variability was used as a criterion for determining which F_3 families were breeding true for certain rachilla lengths and which appeared to be heterozygous for the factors determining this character.

The coefficients of variability ranged from 2.55 ± 0.18 to 3.61 ± 0.24 for the various plots of the Early Gothland parent grown in 1925 (Table 20). In the Garton 784 parent this constant varied from 3.26 ± 0.22 to 5.01 ± 0.34 (Table 21). For the F_2 grown this year the coefficient is 8.28 ± 0.19 (Table 4). Omitting family 19-5-13, which segregated for false wild oats and is therefore not considered in this comparison, the F_3 progenies varied from 4.06 ± 0.27 to 9.09 ± 0.61 (Table 22). In Table 6 a frequency distribution has been made of the coefficients of variability and of mean length of rachilla for the different F_3 families.

TABLE 6.—Variability in length of rachilla in the F_3 progenies grouped by classes for length of rachilla.

Mean Length of Rachilla in units of .1 mm.	Classes for Coefficient of Variability of the F_3 Progenies											
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	Total No.
17	1			1								2
18								2	1	1	3	7
19				1				1	1		1	4
20				1	2		1	1	2	1		8
21			3	1		1	1	3	2	1	1	13
22	1			3	5	1	1		2			13
23				1	2	1						4
24			1	1	1	1		1				5
25		1										1
26		1		1								2
Totals	2	2	4	10	10	4	3	8	8	3	5	59

If the highest coefficient for the parental material (5.01 ± 0.34) is taken as marking the upper limit of variability expected in lines homozygous for a certain length of rachilla, we find there is one family breeding true for a rachilla length of 17, three for 21, one for 22, one for 24, one for 25, and one for 26. Apparently one family has been recovered breeding true for approximately the same length of rachilla as the Garton 784 parent and also one with a rachilla approximately as long as the Early Gothland parent. Between these extremes there are on this basis six other families breeding true for intermediate lengths. If a three factor difference with all factors of equal value be assumed, it would be expected to recover one family breeding true for each extreme and six intermediate homozygous families in a random sample of 64 individuals. The distribution of the homozygous families among the various intermediate classes for length of rachilla is not in very close agreement with what would be expected on such a three factor basis. The F_3 breeding behavior supports the theory that the inheritance of length of rachilla may be put on a multiple factor basis, and also that the factors concerned are either not of equal value or are modified by factors of unequal value.

INHERITANCE OF OTHER CHARACTERS

The inheritance of ligule, panicle type, color, and rachilla pubescence was studied both independently and in their interrelation to each other and to the length of rachilla.

Inheritance of Ligule

The Early Gothland parent in this cross had a leaf with a prominent ligule at the juncture of the leaf blade with the leaf sheath, while the Garton 784 parent was without a ligule. The ligule is ordinarily a very easy character to classify in inheritance. Occasionally, however, a plant is found where the ligule is so poorly developed that it resembles a liguleless plant. In the 60 F_2 plants continued in F_3 one plant should have been classed as liguled that was classed as liguleless and one plant where the opposite was the case (Table 23). The F_1 plants were all liguled indicating that the liguleless character is recessive.

Table 7 presents the results obtained with this character in the F_2 population.

The results obtained are practically identical with the calculated ratio when it is assumed that the inheritance of this character is due to two independently inherited duplicate factors. Love and Craig *(11)* found that inheritance of ligule was due to a one factor difference in

TABLE 7.—Inheritance of ligule in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Liguled	Liguleless			
1923	270	20			
1924	495	34			
1925	411	25			
Observed total	1176	79			
Calculated 15:1 ratio	1176.6	78.4	0.6	5.81	0.10

some varieties of oats and two in others. Garber *(5)* found a two factor difference for the inheritance of this character. Nilsson-Ehle *(13)* found that this character segregated in a monohybrid ratio in one cross while in others its inheritance could be explained on the basis of a two or three factor difference.

In all the different F_2 populations grown it was found that the liguleless condition was very closely associated with the side type of panicle. On account of this relationship between these two characters it is necessary to take both into consideration in analyzing the data for either one in the F_3.

If the liguled condition is dependent upon a two factor difference as the F_2 generation indicates, it would be expected that all liguleless F_2 plants would breed true in the F_3 generation while some of the liguled forms would breed true for this condition and others segregate. In one-half of the segregating lines a 15 to 1 ratio would be expected and in the others a monohybrid ratio.

With the one exception previously mentioned all liguleless F_2 plants continued in the F_3 bred true for this condition. Evidently this plant should have been classed as liguled. The breeding behavior of the F_2 plants in the F_3 progenies for the various characters studied is given in Table 23 of the appendix.

Inheritance of Panicle Type

The Early Gothland parent has an open, spreading panicle while Garton 784 is characterized by a side or "horsemane" type of panicle. The F_1 plants were all intermediate. There seemed to be considerable variation in the expression of this character, some of the F_1 plants resembling the open type more than the side type while in others the reverse was true. The expression of this character appears to be influenced considerably by the environmental conditions and by the stage of maturity of the plants.

The inheritance of panicle type was apparently closely associated with or influenced by the factors producing the liguleless condition. No open liguleless forms were found among any of the F_2 populations grown. This relation suggests that there either is a very close linkage between one of the factors for ligule and the factor or factors for panicle type or that the absence of both of the factors for the liguled condition prevents the factor or factors for open panicle from functioning. Since no open liguleless plants were found among the 1255 F_2 plants grown, it was assumed that the latter was the case. On the assumed basis that the liguled condition is dependent on independently inherited duplicate factors and the open panicle type depends on a single factor difference independent of the two factors for ligule, but inhibited from functioning by the absence of both of the factors for ligule, it would be expected to obtain in F_2 a proportion of 45:15:4 of open panicled liguled plants, side panicled liguled, and side panicled liguleless plants, respectively, or a proportion of 45 open to 19 side panicled plants. The results obtained and the calculated numbers are presented in Table 8.

TABLE 8.—Inheritance of panicle type in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Open Panicle	Side Panicle			
1923	191	99			
1924	380	149			
1925	280	156			
Observed total	851	404			
Calculated 45:19 ratio	882.4	372.6	31.4	10.92	2.88

The agreement of the observed with the calculated is fairly good, the difference being 2.88 times its probable error. In one out of 18 chances a deviation as large as this might be expected from random sampling and, therefore, the hypothesis appears plausible. The F_2 population grown in 1924 agrees much better with the theoretical than do those grown in either of the other two years, the deviation being only a little more than its probable error. The F_3 breeding behavior of the F_2 plants grown in 1924 shows that the classification for panicle type was relatively free from errors. One plant was evidently classed as side which should have been classed as open while in another case the reverse was true.

The breeding behavior of the F_2 plants grown in 1923 when tested in F_3 progenies shows that two plants classified as side in that year should have been classed with the open panicled class. These plants segregated for panicle type and, therefore, were heterozygous for this character. The high percentage of side panicle plants in the 1925 F_2 population suggests that in this year, also, probably a number of the plants classed as side panicled were actually heterozygous for this character and should have been classed with the open panicle forms. When the fact is taken into consideration that this character seems to be considerably influenced by environment and thus overlapping of classes is likely to occur, the data undoubtedly support the theory that in this cross the inheritance of panicle type is due to a single factor difference.

When the two characters, ligule and panicle type, are considered together the results shown in Table 9 were obtained.

TABLE 9.—Inheritance of ligule and panicle type in the F_2 generation.

Year	Ligule Present		Ligule Absent	
	Open	Side	Open	Side
1923	191	79	0	20
1924	380	115	0	34
1925	280	131	0	25
Observed total	851	325	0	79
Calculated 45:15:4 ratio	882.4	294.1	0	78.4

$X^2 = 4.368$ $P = 0.116$

Without correcting for the apparent errors in classification in 1923 and 1925, the observed shows only a fair agreement with the calculated, $P = 0.116$ or 12 times in 100 trials would deviations as great as these be expected from chance selection. If the 1924 population alone is considered, the fit is very close; the calculated being 372, 124, and 33, while the observed were 380, 115, and 34 for the three classes, respectively. X^2 is less than one showing a very close fit. The data give further evidence in support of the assumed factorial analysis for the inheritance of ligule and panicle type.

A summary of the breeding behavior for ligule and panicle type of the F_3 progenies grown from the 1924 F_2 plants in the five-row plots is given in Table 10.

TABLE 10.—Breeding behavior for ligule and panicle type of the F_3 progenies grown in 5-row plots in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies								
		Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	21	8	6	1		6				
Corrected	20	8	6	0		6				
Side liguled	22			1			20			1
Corrected	23			2			21			0
Side liguleless	17						1			16
Corrected	17						0			17
Total (Corrected)	60	8	6	2		6	21			17
Calculated	60	3.1	6.2	10.7		10.6	12.3			17

The 21 F_2 plants classed as open-liguled bred as follows in the F_3 progenies: Eight bred true to the open-liguled condition, six bred true for ligule but segregated for panicle, one bred true for side-liguled, and six segregated for both ligule and panicle. The F_2 plant producing the side-liguled progeny should evidently have been classified as side-liguled in the F_2 and has, therefore, been added to this class in the corrected tabulation.

The number of families in each class obtained from the open-liguled plants agrees fairly well with the calculated.

With the exception of one plant which segregated for ligule all the F_2 plants classed as liguleless bred true for this condition. In the corrected totals the plant segregating for ligule is classed with the side-liguled plants.

All of the F_2 plants classified as side-liguled and continued in the F_3 bred true for side panicle. One plant bred true for the liguleless condition. It should evidently have been classified as liguleless and has been put with this class in the corrected totals.

Of the 23 side-liguled F_2 plants on the corrected basis two bred true for ligule and 21 segregated. The calculated proportion is 10.7 liguled to 12.3 segregating. In this case the observed does not agree very well with the theoretical. Although the numbers are small, it

would seem that for some undetermined reason more of the heterozygous side-liguled plants were selected than of the homozygous ones for continuance in F_3. Some factor may also be present which causes a modification of the expected ratios in this class.

In addition to the foregoing test of the 1924 F_2 plants, 15 additional progenies were grown in single rows. It is realized that the number of plants grown is too small to obtain any definite ratios. The chief aim was to find out if the side and liguleless condition bred true. The results obtained are given in Table 24 of the appendix. Only side panicled plants were used in this supplementary test. All liguleless plants bred true for this condition. One of the side-liguled plants segregated for panicle type and evidently should have been classed as open in the F_2. Two of the other nine side-liguled plants bred true for this condition while seven segregated. Here again the proportion of side-liguled plants breeding true is too small as compared with the calculated.

In addition to the foregoing tests of the F_2 plants grown in 1924, 65 single row families were grown from the 1923 F_2 plants. The results obtained are shown in Table 25 of the appendix. A summary is presented in Table 11.

TABLE 11.—Breeding behavior of F_3 progenies from 1923 F_2 plants grown in single rows in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies: Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	11	3	6			2				
Corrected	13	3	7			3				
Side liguled	34		1	3		1	29			
Corrected	33		0	3		0	30			
Side liguleless	15						1			14
Corrected	14						0			14
Total (Corrected)	60	3	7	3		3	30			14
Calculated	60	2.0	4.0	15.4		7.0	17.6			14

Two plants classified as side panicled in 1923 segregated for panicle in the F_3 test in 1925. They evidently were heterozygous and should have been classed with the open panicle group. Likewise one of the plants classed as liguleless was heterozygous. Again in this test there were too many of the side-liguled F_2 plants segregating for ligule in the F_3 progenies as compared with the class breeding true for ligule and side panicle.

In the three tests made of the breeding behavior of ligule and panicle type in the F_3 progenies, the results obtained agree fairly satisfactorily with the calculated except in the case of the proportion of progenies breeding true for the side-liguled condition and those segregating for ligule and breeding true for side panicle. The results indicate therefore that panicle type is conditioned by a single factor difference. It also seems safe to conclude that the presence of both factors for the liguleless condition in the homozygous state prevents the development of an open panicle.

Nilsson-Ehle *(13)* explained the inheritance of panicle type on the basis of one, two, and three factor differences in various oat crosses. A very close association was found between panicle type and ligule in certain crosses. No open liguleless forms were obtained in any of the crosses made. In one cross between an open-liguled variety and a liguleless side-panicle variety, the results obtained were explained on the basis that two independent duplicate factors for ligule were present in the liguled parent and that both of these factors had an influence on the panicle type. The presence of one of these factors alone would produce an intermediate panicle. The other factor alone would produce an intermediate panicle also, but more dense than the former while the absence of both would result in a side panicle. In other crosses there were apparently factors for panicle type present which did not influence the ligule and also factors which would produce a ligule but did not affect the panicle type.

Quisenberry *(15)* found a two factor difference for panicle type in the oat cross which he studied. Gaines *(3)* and also Wakabayshi *(19)* found irregular segregation for panicle type in the F_2 generation and obtained forms breeding true for the intermediate condition as well as for open and side panicles in the F_3 progenies. Garber *(4)* obtained results indicating a one factor difference for the inheritance of panicle type.

Inheritance of Color

In this cross the Early Gothland has a white grain while the color of the Garton 784 grain is black. The plants in the cross were either classed as black or white, no attempt being made to make further divisions on the basis of intensity of the color. The F_1 plants all had black seed indicating that black is dominant. The segregation in the different F_2 populations is shown in Table 12.

TABLE 12.—Inheritance of color of grain in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Black	White			
1923	223	67			
1924	403	126			
1925	309	127			
Observed total	935	320			
Calculated 3:1 ratio	941.25	313.75	6.25	10.32	0.61

The observed numbers agree very closely with a 3:1 ratio and indicate that color in this cross is due to a single factor difference.

In classifying the F_3 lines for color of grain the first fifteen plants were used as a basis for the determination, except in ten of the segregating lines where a count was made for a verification of the F_2 ratios. A summary of the breeding behavior for color of the F_3 lines is given in Table 13.

TABLE 13.—Summary of breeding behavior for color of the F_3 progenies.

Color of F_2 Plant	F_3 Breeding Behavior			
	Black	Segregating	White	Total Families
Black	13	27		40
White			20	20
Observed	13	27	20	60
Calculated	13.3	26.7	20	60

All F_2 plants classed as white bred true for this color while those classified as black segregated in the ratio of 13 to 27 for lines breeding true for black and lines segregating for color. The calculated is 13.3 to 26.7. The F_3 breeding behavior, therefore, verifies the assumption

that a one factor difference is concerned in the inheritance of this character. These results are in agreement with results obtained by Love and Craig *(10)*, Gaines *(3)*, Garber and Quisenberry *(6)*, and other workers. Nilsson-Ehle *(13)* found three separately inherited color factors each allelomorphic to its absence in a certain oat cross. Through the interaction of these factors four classes for color were obtained, black, gray, yellow, and white. Other workers have also reported similar results when certain crosses were made.

Inheritance of Rachilla Pubescence

The study of the inheritance of pubescence on the rachilla was based on the rachilla of the lower grain. The Early Gothland parent has a rachilla usually with a number of rather fine hairs. The Garton 784 parent has a smooth rachilla with only an occasional hair on some grains. In classifying plants for this character the five seeds from each plant used for making rachilla measurements were also used for making the pubescence determination. A plant was classed as hairy if any hairs were found on any of the grains examined. Since an occasional hair is sometimes found in the smooth parent this classification results in some overlapping of classes. The F_1 plants all had smooth rachillas. The results obtained in the F_2 populations are given in Table 14.

TABLE 14.—Inheritance of rachilla pubescence in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	$\frac{\text{Dev.}}{\text{P. E.}}$
	Smooth	Hairy			
1923	225	65			
1924	355	174			
1925	331	105			
Observed total	911	344			
Calculated 3:1 ratio	941.25	313.75	30.25	10.32	2.94

The total observed numbers agree fairly well with the calculated, the deviation being slightly less than three times its probable error. The proportions in the years 1923 and 1925 agree very closely with the calculated 3:1 ratio while in 1924 there were too many in the hairy class. It would seem that for some reason there was more overlapping of classes for this character in this year than in the other two. A check on this is afforded by the breeding behavior of the 60 F_3 progenies grown from 1924 F_2 plants and which were classified for this character.

In classifying the F_3 families for rachilla pubescence the first fifteen individuals were used as a basis for classifying the families. In a number of the segregating families counts were made of the proportion of smooth and hairy individuals in order to check the ratios obtained in the F_2 generation.

A summary of the breeding behavior for rachilla pubescence in the F_3 progenies is shown in Table 15.

TABLE 15.—Summary of breeding behavior for rachilla pubescence in the F_3 progenies.

Classification of F_2 Plant	F_3 Breeding Behavior			Total Families
	Smooth	Segregating	Hairy	
Smooth	14	27	1	42
Hairy		4	14	18
Observed (Corrected)	14	31	15	60
Calculated	15	30	15	60

From the 42 F_2 plants classified as smooth, 14 lines bred true for this condition, 27 segregated for smooth and hairy, and one bred true for the hairy condition. Evidently this latter plant should have been classified as hairy in the F_2. Fourteen of the F_2 plants, classified as hairy, bred true, while four segregated. On the assumed basis of a one factor difference with smooth condition dominant, these four plants should have been classified as smooth in the F_2. When these F_2 plants are reclassified on the basis of their breeding behavior the number of lines breeding true and the number segregating agree very closely with the calculated. The observed are 14 to 31, and the calculated 15 to 30, respectively. The F_3 breeding behavior, therefore, verifies the assumption that rachilla pubescence in this cross is due to a single factor difference with smooth rachilla dominant.

On the basis of the breeding behavior in the F_3 and assuming that the same proportion of overlapping of classes occurred in the remainder of the F_2 classification in 1924, 30 plants should be changed from the hairy class to the smooth class in the 1924 F_2 population. If this were done, the observed and calculated totals for the three years would be:

	Smooth	Hairy
Observed	941	314
Calculated	941.25	313.75

A number of individuals were, no doubt, classed in the wrong group in the other years, also, so that the close fit is probably coincidental.

Surface *(17)* found that pubescence of the rachilla together with six other characters were completely linked with wild base in a cross between wild and cultivated oats. These were all inherited in a monohybrid ratio. Absence of rachilla hairs was found dominant to the hairy condition.

INTERRELATION OF CHARACTERS

In order to determine if any of the characters studied tended to be associated in their inheritance, the F_2 plants were classified in various combinations. The breeding behavior of the F_3 progenies shows that some of the F_2 plants were wrongly classified for rachilla pubescence. Since only the 1924 F_2 can be checked from the breeding behavior of the F_3 progenies, the F_2 grown in this year is used in the various groupings where rachilla pubescence is one of the characters studied. With the exception of the relation found between the ligule character and panicle type, which has already been discussed, no association in inheritance was found between any of the qualitative characters studied. Table 16 is presented as typical of the method used. All the different qualitative characters studied are included in this table.

In Table 16 the correction for pubescence has been applied as in the other tests with this character. The deviation from the calculated is such as might be expected by chance two times in five trials, $P = 0.410$. From these tests it seems safe to conclude that the four characters are all conditioned by factors that are independently inherited and that the relation between the factor differences which cause panicle type and the liguled condition is of the nature assumed.

CORRELATION OF RACHILLA LENGTH WITH OTHER CHARACTERS

In order to determine if there is any correlation between the inheritance of length of rachilla and any of the other characters studied, the means were calculated for the F_2 plants in each contrasting class for the various characters. If there was no significant difference found in the means between any two contrasted classes it was concluded that no correlation existed between that particular character and the length of rachilla. In addition to this test the means for length of rachilla of the F_3 progenies breeding true for the contrasted characters and those segregating were thrown into frequency distributions from which a mean of means was calculated for each class. The relationship between any character and the length of rachilla could thus be studied in these progenies and the results could then be used as a check on the results obtained in the F_2 generation.

TABLE 16.—Inheritance of ligule, panicle type, color, and rachilla pubescence in the F_2 generation grown in 1924.

Observed and Calculated	Number of F_2 Plants															
	Liguled								Liguleless							
	Open Panicle				Side Panicle				Open Panicle				Side Panicle			
	Black		White		Black		White		Black		White		Black		White	
	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy
Observed	192	102	68	18	49	35	20	11	0	0	0	0	19	6	7	2
Observed (Corrected)	209.8	84.2	71.1	14.9	55.1	28.9	21.9	9.1	0	0	0	0	20.0	5.0	7.3	1.7
Calculated	209.2	69.7	69.7	23.2	69.7	23.2	23.2	7.7	0	0	0	0	18.6	6.2	6.2	2.1

$X^2 = 11.411$ $P = 0.410$

Pubescence and Length of Rachilla

In Table 17 the means for the pubescent and the smooth segregates in the F_2 populations and the means for the F_3 progenies breeding true for the hairy condition, segregating, and breeding true for smooth rachilla are compared.

The data show that in all three F_2 populations the means for the length of rachilla were greater for the hairy segregates than for the smooth and in no case was the difference less than ten times its probable error. This is taken as evidence that the characters pubescence of rachilla and length of rachilla are definitely associated in inheritance.

As a further test of this relationship, coefficients of contingency were calculated for pubescence and length of rachilla in the F_2 generations. The following coefficients were obtained in the various F_2 populations: 1923, $C = 0.346 \pm 0.046$; 1924, $C = 0.416 \pm 0.033$; 1924, $C = 0.321 \pm 0.039$. In all three years there was a positive correlation between these two characters. This method of analysis, therefore, also shows the linkage relation which exists between pubescence and length of rachilla in their inheritance.

When the F_3 generation is considered it is also seen that the families breeding true for the hairy condition had a greater mean length of rachilla than either the segregating families or those breeding true for smooth rachilla. The families segregating for this character also had a greater mean length of rachilla than those breeding true for the smooth condition. In no case was the difference less than three times its probable error. This is further confirmation that these two characters are definitely associated in inheritance.

Since it has been shown that the inheritance of pubescence of the rachilla is dependent upon a single factor difference and that the length of rachilla may be explained on a multiple factor basis, it seems logical to conclude that the factor determining the inheritance of pubescence of the rachilla is in the same linkage group as one or more of the factors determining the length of rachilla.

TABLE 17.—Length of rachilla in the pubescent and smooth rachilla segregates in the F_2 generations and the mean length of rachilla in the F_3 progenies breeding true for pubescent rachilla, segregating, and breeding true for smooth rachilla.

Character of Pubescence	Generation	Year	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Difference	Diff. / P. E.
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
Smooth	2	1923	2	3	16	25	48	48	26	25	18	12	2					225	21.089±0.091		
Hairy	2	1923					1	14	16	10	9	6	4	4			1	65	23.138±0.168	2.049±0.191	10.7
Smooth	2	1924	4	11	29	66	73	74	54	25	10	6	3					355	20.485±0.066		
Hairy	2	1924		1	3	5	13	25	38	29	33	18	5	3	1			174	22.615±0.098	2.130±0.118	18.0
Smooth	2	1925	2	6	18	53	85	73	56	29	6	3						331	20.592±0.058		
Hairy	2	1925		1	1	4	12	20	31	18	10	5		3				105	22.029±0.115	1.437±0.129	11.1
Smooth	3	1925		2	3	2	3		3	1								14	19.643±0.345	2.957±0.447*	6.6
Segregating	3	1925			4	2	4	9	8		3		1					31	21.065±0.226	1.422±0.412**	3.4
Hairy	3	1925					1	4	3	3	2	1	1					15	22.600±0.284	1.535±0.363†	4.2

*Between hairy and smooth rachilla progenies.
**Between smooth and segregating progenies.
†Between hairy and segregating progenies.

Ligule, Panicle Type, Color of Grain, and Length of Rachilla

The means for length of rachilla of the various classes for ligule, panicle type, and color were calculated in the same manner as these were calculated for the classes for pubescence of the rachilla. A summary of the results obtained is given in Table 18.

TABLE 18.—Mean length of rachilla in different contrasted classes in the F_2 and F_2 generations.

Description	Generation	Number of Plants and Mean Length of Rachilla in Units of .1 mm.					
		1923		1924		1925	
		No.	Means	No.	Means	No.	Means
Liguled	F_2	270	21.548±0.090	495	21.178±0.065	411	20.934±0.057
Liguleless	F_2	20	21.550±0.311	34	21.294±0.222	25	21.000±0.275
Liguled	F_3					16	20.875±0.331
Seg. for ligule	F_3					27	21.370±0.296
Liguleless	F_3					17	20.882±0.291
Open panicle	F_2	191	21.534±0.110	381	21.097±0.074	280	20.811±0.069
Side panicle	F_2	99	21.576±0.140	148	21.412±0.114	156	21.167±0.094
Open panicle	F_3					8	20.125±0.526
Seg. for panicle	F_3					12	21.250±0.451
Side panicle	F_3					40	21.250±0.205
Black grain	F_2	223	21.453±0.102	403	20.980±0.070	309	20.861±0.068
White grain	F_2	67	21.866±0.158	126	21.841±0.125	127	21.126±0.097
Black grain	F_3					15	20.800±0.338
Seg. for color	F_3					25	20.400±0.267
White grain	F_3					20	22.150±0.279

It is evident from a consideration of the data given in Table 18 that there was no correlation between the inheritance of the length of rachilla and the inheritance of either ligule or panicle type. The differences between the means for the various classes are not significant in the light of their probable errors.

The differences in length of rachilla between the black and white grained classed in the F_2 generation for the three years were 0.413 ± 0.188, 0.861 ± 0.143, and 0.265 ± 0.118. In two out of the three years the differences were not large enough to be considered significant. In the other year, 1924, the difference was approximately six times its probable error and shows that the white seeded plants had the longer rachillas that year. The fact that there is only a difference in one year out of the three indicates that if this difference was due to inheritance, the association between color and length of rachilla is very loose.

In the F_3 generation there was no significant difference in length of rachilla between the families breeding true for black and those segregating for color. The actual length for the segregating families was less than for the families breeding true for black color. The differences in mean length of rachilla between the segregating and white families was 1.750 ± 0.386 units. This difference is significant in the light of its probable error. The difference between the black seeded families and the white was 1.350 ± 0.438 which may also be considered as significant. These results seem to point to a slight association between the inheritance of color and length of rachilla.

SUMMARY

A cross was made between Early Gothland and Garton 784 two varieties of oats differing in certain characters. A study was made of the inheritance of the length of the rachilla, ligule, panicle type, color, and pubescence of the rachilla. From the results obtained certain conclusions and deductions can be drawn.

1.—The length of rachilla was found to be a very stable size character and was not greatly influenced by environmental conditions.

2.—The length of rachilla in the F_1 plants was intermediate between the two parents. The F_2 individuals ranged from one parent to the other for length of rachilla. From 60 F_3 progenies grown, one apparently homozygous line was recovered with a rachilla length as short as the short parent, and one F_3 family with a rachilla length approximately as long as the longer parent. Families apparently homozygous for rachilla lengths intermediate between these extremes were also recovered. The inheritance of rachilla length can be explained on the basis of multiple factors for length of rachilla. The results indicated that the factors involved were not of equal value in determining the length of rachilla.

3.—The ligule of the leaf was found to be determined by duplicate factors giving a ratio of 15 liguled to 1 liguleless plant in the F_2 generation.

4.—The panicle type was found to be controlled by a single factor difference. The presence of the two factors for the liguleless condition in the homozygous state prevented the factor for open panicle, if present, from functioning and resulted in producing a side panicle. No open panicled liguleless forms were found.

5.—Black color of grain was dominant to white. Inheritance of color was controlled by a single factor difference.

6.—Pubescence of the rachilla was found to be recessive to the smooth condition and was controlled by a single factor difference.

7.—No evidence of linkage was found between the factors for ligule, panicle type, color, or pubescence. All seemed to be inherited independently of each other except for the duplicate relationship between the two factors for ligule and their common relationship to the factor for panicle type.

8.—No evidence was found of linkage between any of the factors for length of rachilla and ligule or panicle type. Some of the data indicated a possible loose linkage between color and length of rachilla.

9.—A close linkage was found between at least one of the factors or group of factors for length of rachilla and the factor for pubescence of the rachilla.

SUPPLEMENT

Since this paper was originally submitted for publication, additional data have been obtained by growing F_4 families from a number of selected F_3 plants. These F_4 families were grown during the summer of 1926 and handled in a way similar to that in which the F_3 and other material was handled in the previous years of the study. In all there were twelve F_4 families grown including progenies from single plants from each of the eight F_3 families which were apparently breeding true for certain rachilla lengths. The data obtained are given in Table 26 of the appendix.

The highest coefficient of variability obtained in the parental material grown in 1926 was 5.84 ± 0.38. If this is taken as the upper limit for the coefficients of variability for homozygous lines it is found that all but two of the F_4 lines are apparently homozygous. Among these are included all F_4 progenies from the F_3 families which were classed as homozygous and also two lines from F_3 families which were classified as heterozygous. If an F_3 family were homozygous for a certain length of rachilla it would be expected that it would continue to show this condition in the F_4 also. Either heterozygous or homozygous F_4 lines might be expected from a heterozygous F_3 family. All data show a very close correlation between the length of the rachilla in the F_3 and F_4 generations.

The F_4 data substantiate the conclusion previously reached that a number of F_3 families had been obtained that were breeding true for certain rachilla lengths.

Data on the other characters studied were also obtained for the F_4 families. These data are not presented here but in all cases they substantiate the conclusions drawn from the study of the previous generations.

LITERATURE CITED

(1) CAPORN, A. ST. CLAIR
1918. AN ACCOUNT OF AN EXPERIMENT TO DETERMINE THE HEREDITY OF EARLY AND LATE RIPENING IN AN OAT CROSS. Jour. Genetics, 7:247-257.

(2) EAST, E. M.
1916. STUDIES ON SIZE INHERITANCE IN NICOTIANA. Genetics, 1:164-176.

(3) GAINES, E. G.
1917. INHERITANCE IN WHEAT, BARLEY, AND OAT HYBRIDS. Wash. Agr. Exp. Sta. Bul. 135.

(4) GARBER, R. J.
1922. INHERITANCE AND YIELD WITH PARTICULAR REFERENCE TO RUST RESISTANCE AND PANICLE TYPE IN OATS. Univ. of Minn. Tech. Bul. 7.

(5) ——————
1922. ORIGIN OF FALSE WILD OATS. Jour. Heredity, 13:40-48.

(6) ——————, AND QUISSENBERRY, K. S.
1926. A STUDY OF CORRELATED INHERITANCE IN A CERTAIN AVENA CROSS. W. Va. Agr. Exp. Sta. Bul. 217.

(7) GRIFFEE, FRED
1925. CORRELATED INHERITANCE OF BOTANICAL CHARACTERS IN BARLEY, AND MANNER OF REACTION TO HELMINTHOSPORIUM SATIVUM. Jour. Agr. Res., 30:915-935.

(8) HAYES, H. K., AND GARBER, R. J.
1921. BREEDING CROP PLANTS. 328 pp. New York.

(9) LINDSTROM, E. W.
1924. A GENETIC LINKAGE BETWEEN SIZE AND COLOR FACTORS IN THE TOMATO. Science, 60:182-183.

(10) LOVE, H. H., AND CRAIG, W. T.
1918. THE RELATION BETWEEN COLOR AND OTHER CHARACTERS IN CERTAIN AVENA CROSSES. Am. Nat. 52:369-383.

(11) ——————
1918. SMALL GRAIN INVESTIGATIONS. Jour. Heredity 9:67-76.

(12) NILSSON-EHLE, H.
1908. EINIGE ERGEBNISSE VON KREUZUNGEN BEI HAFER UND WEIZEN. Bot. Notiser, Lund., pp. 257-298.

(13) ——————,
1909. KREUZUNGSUNTERSUCHUNGEN AN HAFER UND WEIZEN. Lunds Univ. Arsskr. N. F. Afd. 2, Bd. 5, Nr. 2, pp. 122.

(14) NOLL, C. F.
1925. STUDIES OF INHERITANCE OF EARLINESS IN CERTAIN AVENA CROSSES. Penn. Agr. Exp. Sta. Bul. 194.

(15) QUISENBERRY, K. S.
1926. CORRELATED INHERITANCE OF QUANTITATIVE AND QUALITATIVE CHARACTERS IN OATS. W. Va. Agr. Exp. Sta. Bul. 202.

(16) SAX, KARL
1923. THE ASSOCIATION OF SIZE DIFFERENCES WITH SEED-COAT PATTERN AND PIGMENTATION IN PHASEOLUS VULGARIS. Genetics 8:552-560.

(17) SURFACE, F. M.
1916. STUDIES ON OAT BREEDING. III. ON THE INHERITANCE OF CERTAIN GLUME CHARACTERS IN THE CROSS AVENA FATUA X AVENA SATIVA VAR. KHERSON. Genetics 1:252-286.

(18) TEDIN, H., AND TEDIN, O.
1926. CONTRIBUTIONS TO THE GENETICS OF BARLEY. I. TYPE OF SPIKE, NAKEDNESS, AND HEIGHT OF PLANTS. Hereditas Ed. 7, Haft 2, 151-160.

(19) WAKABYASHI, S.
1921. A STUDY OF HYBRID OATS, AVENA STERILIS X AVENA ORIENTALIS. Jour. Am. Soc. Agron., 13:259-266.

(20) ZINN, JACOB, AND SURFACE, F. M.
1917. STUDIES ON OAT BREEDING. V. THE F_1 AND F_2 GENERATIONS OF A CROSS BETWEEN A NAKED AND A HULLED OAT. Jour. Agr. Res., 10:293-312.

APPENDIX

TABLE 19.—Statistical constants for length of rachilla, for samples of 29, 48, 58, and 96 plants taken from the F_2 generation. grown in 1923.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1			2	1	3	6	6	4	2	2	1	2				29	22.172±0.289	2.306±0.204	10.40±0.93
2			3	4	4	5	3	2	6	2						29	21.414±0.262	2.190±0.194	10.23±0.92
3	1	0	0	2	8	5	5	3	2	2	1					29	21.448±0.262	2.094±0.185	9.76±0.86
4			4	2	3	8	3	2	4	1	1	0	0	0	1	29	21.621±0.333	2.657±0.235	12.29±1.10
5		1	3	3	2	5	6	7	0	2						29	21.241±0.256	2.045±0.181	9.63±0.85
6	1	2	0	2	5	9	0	5	4	0	0	1				29	21.207±0.295	2.354±0.208	11.10±0.99
7			1	1	9	7	4	5	0	1	1					29	21.310±0.213	1.704±0.151	8.00±0.71
8			1	4	5	4	7	4	1	2	0	1				29	21.552±0.256	2.044±0.181	9.48±0.84
9			1	5	3	8	4	1	2	4	1					29	21.586±0.272	2.174±0.193	10.07±0.90
10			1	1	7	5	4	2	6	2	1					29	21.931±0.253	2.016±0.179	9.19±0.81
1		1	3	4	4	10	10	7	2	6	1					48	21.708±0.206	2.121±0.146	9.77±0.67
2			3	4	9	10	5	4	6	5	0	1	0	0	1	48	21.833±0.240	2.461±0.169	11.27±0.79
3	1	0	2	6	9	13	8	3	3	3						48	21.063±0.183	1.887±0.130	8.91±0.61
4		1	1	4	4	12	7	7	8	2	2					48	21.917±0.195	2.008±0.138	9.16±0.63
5			2	2	11	8	7	10	1	2	3	2				48	21.917±0.214	2.197±0.151	10.02±0.70
6	1	1	5	5	9	10	5	4	7	0	0	1				48	20.937±0.215	2.204±0.152	10.53±0.73

(Continued)

TABLE 19.—Concluded.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1	1	2	2	3	8	15	6	9	6	2	1	3				58	21.690±0.211	2.380±0.149	10.97±0.69
2			4	5	13	12	7	7	6	3	1					58	21.362±0.174	1.963±0.123	9.19±0.57
3	1	0	1	6	13	9	12	7	3	4	1	1				58	21.500±0.183	2.070±0.130	9.63±0.60
4			5	7	6	16	7	3	6	5	2	0	0	0	1	58	21.603±0.215	2.428±0.152	11.24±0.71
5		1	4	4	9	10	10	9	6	4	1					58	21.586±0.182	2.060±0.129	9.54±0.60
1		2	4	8	8	22	17	14	10	8	3					96	21.813±0.142	2.068±0.101	9.48±0.46
2			5	6	20	18	12	14	7	7	3	3	0	0	1	96	21.875±0.161	2.333±0.114	10.66±0.53
3	2	1	7	11	18	23	13	7	10	3	0	1				96	21.000±0.142	2.056±0.100	9.79±0.48
1	2	3	16	25	49	62	42	35	27	18	6	4	0	0	1	290	21.652±0.083	2.089±0.059	9.65±0.27

TABLE 20.—Statistical constants for length of rachilla of the Early Gothland parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficient of Variability
	25	26	27	28	29	30				
604–606		15	27	7	1		50	26.880±0.068	0.711±0.048	2.64±0.18
625–627	2	10	24	13		1	50	27.040±0.085	0.894±0.060	3.31±0.22
648–650	3	16	16	10			45	26.733±0.088	0.879±0.062	3.29±0.23
679–681	6	17	20	7			50	26.560±0.083	0.875±0.059	3.29±0.22
711–713	3	12	24	10	1		50	26.880±0.082	0.863±0.058	3.21±0.22
745–747	4	22	17	7			50	26.540±0.079	0.830±0.056	3.13±0.21
779–781		17	23	7			47	26.787±0.067	0.682±0.047	2.55±0.18
808–810	1	8	25	16			50	27.120±0.070	0.739±0.050	2.72±0.18
839–841	4	15	21	7	1		48	26.708±0.087	0.889±0.061	3.33±0.23
873–875	3	13	23	11			50	26.840±0.079	0.833±0.056	3.10±0.21
905–907	1	12	24	9	4		50	27.060±0.086	0.904±0.061	3.34±0.22
936–938	1	10	25	11	1		48	27.021±0.076	0.777±0.053	2.88±0.20
967–969	2	8	27	12	1		50	27.040±0.076	0.799±0.054	2.95±0.20
1003–1005	4	14	22	6	1		47	26.702±0.086	0.673±0.061	3.27±0.23
1035–1037	4	9	30	4			47	26.723±0.072	0.735±0.051	2.75±0.19
1061–1063	2	7	26	14	1		50	27.100±0.077	0.806±0.054	2.97±0.20
1081–1083	3	7	29	8	3		50	27.020±0.084	0.883±0.060	3.27±0.22
1114–1116	2	11	19	14	4		50	27.140±0.093	0.980±0.066	3.61±0.24

TABLE 21.—Statistical constants for length of rachilla of the Garton 784 parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficient of Variability
	14	15	16	17	18	19				
607–609		3	24	20	3		50	16.460±0.067	0.699±0.047	4.25±0.29
628–630		2	26	21	1		50	16.420±0.058	0.603±0.041	3.67±0.25
651–653		3	34	13			50	16.200±0.050	0.529±0.036	3.26±0.22
682–684		3	32	15			50	16.240±0.052	0.550±0.037	3.39±0.23
714–716		4	27	19			50	16.300±0.058	0.608±0.041	3.73±0.25
784–750		15	29	5	0	1	50	15.860±0.071	0.749±0.051	4.72±0.32
782–784		5	27	15	3		50	16.320±0.070	0.733±0.049	4.49±0.30
811–813		9	31	10			50	16.020±0.059	0.616±0.042	3.84±0.26
842–844		7	25	16	2		50	16.260±0.071	0.743±0.050	4.57±0.31
876–878	1	5	24	18	1		49	16.265±0.072	0.750±0.051	4.61±0.31
908–910		3	24	18	5		50	16.500±0.072	0.755±0.051	4.58±0.31
939–941		5	31	12	2		50	16.220±0.064	0.672±0.045	4.14±0.28
970–972		14	26	9	0	1	50	15.960±0.076	0.799±0.054	5.01±0.34
1006–1008		9	23	13	2		47	16.170±0.077	0.780±0.054	4.82±0.34
1038–1040		8	30	8	2		48	16.083±0.068	0.702±0.048	4.36±0.30
1064–1066		11	30	8	1		50	15.980±0.065	0.678±0.046	4.24±0.29
1084–1086		4	33	13			50	16.180±0.053	0.555±0.037	3.43±0.23
1117–1119		7	21	20	2		50	16.340±0.073	0.764±0.052	4.68±0.31

TABLE 22.—Breeding behavior for length of rachilla of the F_3 progenies grown in 1925.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
654–658	18–1–25	21.2				1	2	5	11	13	8	1	7	1	1				50	21.180±0.181	8.94±0.60
659–663	18–1–29	20.6					1	10	20	9	6	4							50	20.420±0.116	5.96±0.40
664–668	18–1–32	21.6						2	9	14	9	12	3	1					50	21.660±0.132	6.37±0.43
669–673	18–1–66	20.0					3	5	11	13	8	9		1					50	21.000±0.147	7.31±0.49
674–678	18–1–70	17.2		5	6	13	16	5	2	1	2								50	17.600±0.153	9.09±0.61
685–689	18–2–29	19.4			1	2	2	10	11	9	7	7	1						50	20.480±0.169	8.64±0.58
691–695	18–4–22	17.8	1	1	7	7	12	13	5	4									50	18.140±0.153	8.82±0.59
696–700	18–4–42	23.0								2	7	10	14	7	6	4			50	24.020±0.150	6.53±0.44
701–705	18–4–47	22.2							9	15	8	17	1						50	21.720±0.111	5.37±0.36
706–710	18–4–54	19.8				3	2	5	12	10	13	2	2	1					50	20.740±0.165	8.34±0.56
717–721	18–4–56	16.0		1	11	20	15	3											50	17.140±0.086	5.29±0.36
722–726	18–4–58	18.2		1		8	5	12	10	8	5	1							50	19.400±0.164	8.87±0.60
727–731	18–4–68	22.4					2	5	10	16	5	8	2	2					50	21.180±0.156	7.71±0.52
732–736	18–4–76	18.8				1	2	8	11	10	8	8	1	1					50	20.880±0.160	8.05±0.54
737–739	18–4–77	27.8											10	13	13	2	6	1	45	25.867±0.140	5.38±0.38
740–744	18–4–104	19.2		1	1	5	8	17	10	4	3	1							50	19.120±0.149	8.14±0.55
751–753	18–5–31	17.0			1	2	13	16	10	1									43	18.814±0.102	5.28±0.38

(Continued)

TABLE 22.—Continued.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
754–758	18–5–32	21.0				1	4	11	17	10	3	2	2						50	20.400±0.135	6.93±0.47
759–763	18–5–33	16.4			4	11	12	10	10	2	1								50	18.420±0.136	7.76±0.52
764–768	8–5–34	21.8					1	3	6	10	12	11	2	4	1				50	21.920±0.164	7.84±0.53
769–773	18–5–42	20.0				4	7	15	12	6	3	2	1						50	19.620±0.150	8.02±0.54
774–778	18–5–43	22.2					4	5	22	11	7	1							50	20.300±0.108	5.60±0.38
785–789	18–6–117	19.0		2	4	14	12	12	4	2									50	17.960±0.131	7.63±0.51
790–792	18–6–124	26.8						2	2	9	21	6	7	3					50	22.200±0.131	6.18±0.42
793–797	18–6–131	18.0		3	1	8	16	11	6	2	3								50	18.440±0.154	8.75±0.59
798–802	18–6–135	24.8							1		3	10	16	11	6	2	1		50	24.260±0.137	5.94±0.40
803–807	18–6–136	19.2					2	3	10	12	9	9	4		1				50	21.440±0.157	7.70±0.52
814–818	18–6–155	22.0						3	12	17	10	4	2	1	1				50	21.300±0.138	6.79±0.46
819–823	18–6–169	16.0		3	20	25	2												50	16.520±0.064	4.06±0.27
824–828	19–1–26	17.4				9	14	9	10	6	2								50	18.920±0.136	7.54±0.51
829–833	19–1–34	20.8					2	15	15	9	7	2							50	20.200±0.118	6.10±0.41
834–838	19–1–36	20.8				2	9	15	8	10	4	2							50	19.700±0.141	7.48±0.50
845–849	19–1–41	23.8							2	5	13	13	12	4	1				50	22.880±0.126	5.77±0.39
850–852	19–1–65	16.0		3	6	5	12	8	2	2									38	17.789±0.167	8.57±0.66

(Continued)

TABLE 22.—Continued.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm. 14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total No.	Means	Variability Coefficient of
853–857	19–3–22	22.6						1	2	5	14	13	13	1	1				50	22.680±0.127	5.88±0.40
858–862	19–3–28	24.4						2	5	14	13	13	3						50	21.780±0.116	5.61±0.38
863–867	19–3–49	25.6									2	17	14	7	8	2			50	24.160±0.121	5.26±0.35
868–872	19–3–55	21.2						4	6	12	5	12	7	4					50	22.040±0.164	7.80±0.53
879–883	19–3–61	19.0			3	8	19	8	8	3	1								50	18.460±0.130	7.37±0.50
884	19–4–27	25.8								4	3	3	3	1	1				15	22.800±0.264	6.64±0.82
885–889	19–4–40	23.2							3	15	15	10	4	3					50	22.120±0.120	5.69±0.38
890–894	19–4–52	22.4						1	9	18	9	8	5						50	21.580±0.122	5.94±0.40
895–899	19–4–88	24.8										15	19	11	1	3		1	50	24.240±0.120	5.19±0.35
900–904	19–4–89	21.4							2	8	14	11	13	1	1				50	22.640±0.123	5.71±0.38
911–915	19–4–94	23.8							2	13	19	14	2						50	22.020±0.088	4.21±0.28
916–920	19–5–13	19.8				1	1	4	11	14	4	3			1	7	3	1	50	22.200±0.297	14.01±0.96
921–925	19–5–15	25.6										4	15	15	11	5			50	24.960±0.106	4.46±0.30
926–930	19–5–16	21.4						5	18	14	11	2							50	20.740±0.099	4.99±0.34
931–935	19–5–17	20.4					1	13	8	9	12	4	2		1				50	20.880±0.159	7.99±0.54
942–946	19–5–32	25.4						1	3	10	15	9	9	3					50	22.340±0.133	6.24±0.42
947–951	19–5–33	23.8						1	5	14	13	6	7	4					50	22.100±0.143	6.79±0.46

(Continued)

TABLE 22.—Concluded.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
952–956	19–5–35	26.8								1	3	14	10	9	7	2	2	2	50	24.480±0.171	7.32±0.49
957–961	19–5–36	23.4							4	12	8	13	11	2					50	22.420±0.131	6.12±0.41
962–966	19–5–38	20.4					1	10	6	14	12	6	1						50	20.960±0.135	6.75±0.45
973–977	19–6–21	22.4						3	17	20	6	3	1						50	20.840±0.100	5.02±0.34
978–982	19–6–27	20.8				2	3	10	13	12	5	3	1	1					50	20.360±0.156	8.03±0.54
983–987	19–6–32	20.6					1	4	12	16	13	4							50	20.960±0.110	5.48±0.37
988–992	19–6–33	21.6						2	7	14	20	7							50	21.460±0.098	4.77±0.32
993–997	19–6–40	25.6										1	7	18	13	9	2		50	25.560±0.106	4.37±0.29
998–1002	19–6–51	23.6						1	3	12	13	12	7	2					50	22.220±0.127	5.99±0.40

TABLE 23.—Breeding behavior of F_3 progenies for ligule, panicle type, grain color, and rachilla pubescence.

1925 Row Number	N. H. N	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
654–658	18–1–25	P	85		O	85		B		x		Sm.		x		85
659–663	18–1–29	P	83	7	O	63	27	B		x		Sm.	x			90
664–668	18–1–32	P	64	18	S		82	B		x		Sm.		x		82
669–673	18–1–66	A		86	S		86	B		x		Sm.		x		86
674–678	18–1–70	P	58	16	O	41	33	B		x		Sm.		x		74
685–689	18–2–29	P	86		O	69	17	W			x	Sm.		x		86
691–695	18–4–22	P	59	25	S		84	W			x	Sm.	x			84
696–700	18–4–42	P		85	O	66	19	B	x			H			x	85
701–705	18–4–47	P	63	26	S		89	W			x	Sm.		x		89
706–710	18–4–54	A		79	S		79	B	x			Sm.		x		79
717–721	18–4–56	P	73	7	O	49	31	B	x			Sm.	x			80
722–726	18–4–58	P	65	21	S		86	B	x			Sm.		x		86
727–731	18–4–68	A		82	S		82	W			x	Sm.		x		82
732–736	18–4–76	P	63	19	S		82	W			x	Sm.		x		82
737–739	18–4–77	P	35	11	S		46	W			x	H			x	46
740–744	18–4–104	P	60	19	S		79	B		x		Sm.	x			79
751–753	18–5–31	P	34	11	S		45	B		x		H		x		45
754–758	18–5–32	A		90	S		90	W			x	Sm.		x		90
759–763	18–5–33	P	79		O	79		B		x		Sm.		x		79
764–768	18–5–34	P	71	18	S		89	W			x	Sm.		x		89
769–733	18–5–42	P	71		S		71	B		x		Sm.		x		71

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 23.—Continued.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
774–778	18–5–43	A		80	S		80	B		x		Sm.	x			80
785–789	18–6–117	A		91	S		91	B		x		Sm.	x			91
790–792	18–6–124	P		50	O	28	22	W			x	H			x	50
793–797	18–6–131	A		77	S		77	B		x		Sm.	x			77
798–802	18–6–135	A		83	S		83	W			x	Sm.		x		83
803–807	18–6–136	A		88	S		88	B	x			Sm.		x		88
814–818	18–6–155	P	73	18	S		91	B	x			H			x	91
819–823	18–6–169	P	80		O	80		B	x			Sm.	x			80
824–828	19–1–26	P	70	15	S		85	B		x		Sm.	x			85
829–833	19–1–34	P	60	18	S		78	B		x		Sm.		x		78
834–838	19–1–36	P	84		O	84		B		x		H			x	84
845–849	19–1–41	A		89	S	89		W			x	Sm.	x			89
850–852	19–1–65	P	41		O	41		B		x		Sm.		x		41
853–857	19–3–22	P	59	25	S		84	B		x		H			x	84
858–862	19–3–28	P	89		O	89		W			x	Sm.	x			89
863–867	19–3–49	P	62	23	S		85	B	x			Sm.		x		85
868–872	19–3–55	A		87	S		87	B	x			Sm.		x		87
879–883	19–3–61	A		76	S		76	B		x		Sm.	x			76
884	19–4–27	P	15		O		15	B		x		H			x	15
885–889	19–4–40	P	80	3	O	32	51	W			x	Sm.	x			83
890–894	19–4–52	A		81	S		81	W			x	H		x		81
895–899	19–4–88	A		73	S		73	B		x		Sm.		x		73
900–904	19–4–89	P	66	22	S		88	W			x	H			x	88

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 23.—Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
911–915	19–4–94	P	79		O	58	21	B		x		H			x	79
916–920	19–5–13	A	61	24	S		85	W			x	Sm.		x		85
921–925	19–5–15	P	63	22	S		85	B		x		Sm.			x	85
926–930	19–5–16	P	78		O	59	19	W			x	H			x	78
931–935	19–5–17	P	87		O	70	17	B	x			H			x	87
943–946	19–5–32	P	58	21	S		79	B		x		Sm.		x		79
947–951	19–5–33	P	66	17	S		83	B		x		H			x	83
952–956	19–5–35	P	90		O	90		W			x	H			x	90
957–961	19–5–36	P	64	21	S		85	W			x	Sm.	x			85
962–966	19–5–38	A		75	S		75	B	x			Sm.		x		75
973–977	19–6–21	A		86	S		86	B	x			H			x	86
978–982	19–6–27	P		87	S		87	B	x			Sm.	x			87
983–987	19–6–32	P	54	22	S		76	B		x		H		x		76
988–992	19–6–33	P	79		O	79		B		x		H		x		79
993–997	19–6–40	P	75	8	O	50	33	W			x	Sm.		x		83
998–1002	19–6–51	P	69	5	O	45	29	B		x		Sm.		x		74

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 24.—Breeding behavior for ligule and panicle type of single row F_3 progenies grown from 1924 F_2 plants.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total No.
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1087	18–1–22	P	18		S		18	18
1088	18–1–33	P	14	3	S	9	8	17
1089	18–1–41	P	15	5	S		20	20
1090	18–4–18	P	15	5	S		20	20
1091	18–4–21	P	11	3	S		14	14
1092	18–4–65	P	14	5	S		19	19
1093	18–6–163	A		14	S		14	14
1094	19–3–17	A		16	S		16	16
1095	19–4–47	A		17	S		17	17
1096	19–4–92	A		19	S		19	19
1097	19–5–25	A		17	S		17	17
1098	19–6–22	P	9	7	S		16	16
1099	19–6–41	P	13	3	S		16	16
1100	19–6–43	P	17		S		17	17
1101	19–6–53	P	17	1	S		18	18

TABLE 25.—Breeding behavior for ligule and panicle type of single row F_3 progenies grown from 1923 F_2 plants.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No F_3 Plants		
			P	A		O	S	
1009	18–1–1	P	16		O	16		16
1010	18–1–3	P	12	3	S		15	15
1011	18–1–8	P	9	4	S		13	13
1012	18–1–17	A	7	4	S		11	11
1013	18–1–19	P	8	5	S		13	13
1014	18–2–8	P	13		O	13		13
1015	18–2–11	P	5	5	S		10	10
1016	18–2–12	A		6	S		6	6
1017	18–3–1	P	13	3	S		16	16
1018	18–3–4	P	13	1	O	10	4	14
1019	18–3–10	P	10	5	S		15	15
1020	18–3–18	A		13	S		13	13
1021	18–3–21	P	7	2	S		9	9
1022	18–3–25	P	8	1	S		9	9
1023	18–4–9	A		13	S		13	13
1024	18–5–2	A		11	S		11	11
1025	18–5–3	P	13		S		13	13
1026	18–5–8	P	18		O	18		18
1027	18–5–24	P	12	1	S		13	13
1028	18–6–8	A		14	S		14	14
1029	18–6–11	P	5	2	S		7	7
1030	18–6–13	P	9	5	S		14	14
1031	18–6–16	P	12	3	S		15	15
1032	18–6–4	P	5	7	S		12	12
1033	18–6–23	A		16	S		16	16

(Continued)

TABLE 25.—Continued.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1034	18–6–29	P	9	4	S		13	13
1041	18–6–33	P	8	6	S		14	14
1042	18–6–38	P	11	3	S		14	14
1043	18–6–42	P	9	4	S		13	13
1044	18–6–48	P	15		S	8	7	15
1045	18–6–51	P	9	5	S		14	14
1046	18–6–58	P	11		O	7	4	11
1047	18–6–60	P	12		O	5	7	12
1048	18–6–78	A		13	S		13	13
1049	18–6–85	P	11		O	5	6	11
1050	18–6–86	P	13		S		13	13
1051	18–6–89	P	15	1	O	9	7	16
1052	18–6–92	A		13	S		13	13
1053	18–6–94	P	12	3	S		15	15
1054	18–6–102	P	12	4	S		16	16
1055	18–6–103	A		13	S		13	13
1056	18–6–106	P	13		O	7	6	13
1057	18–6–108	P	13		S		13	13
1058	18–6–109	P	10	7	S		17	17
1059	18–6–111	P	12		O	5	7	12
1060	18–6–113	P	16		O	11	5	16
1067	19–1–1	P	14	6	S		20	20
1068	19–1–2	A		16	S		16	16
1069	19–1–20	A		14	S		14	14
1070	19–2–5	A		16	S		16	16
1071	19–3–4	A		17	S		17	17

(Continued)

TABLE 25.— Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1072	19–3–5	P	8	3	S		11	11
1073	19–4–1	P	13	5	S		18	18
1074	19–4–5	P	9	4	S		13	13
1075	19–5–2	A		10	S		10	10
1076	19–5–4	P	15	2	S		17	17
1077	19–6–2	P	13	6	S		19	19
1078	19–6–12	P	15	2	S		17	17
1079	19–6–13	P	13	2	S		15	15
1080	19–6–14	P	11	4	S	7	8	15

TABLE 26.—Statistical constants for length of rachilla of the parents and of the F_4 progenies grown in 1926.

1926 Row Number	Material	F_3 Rachilla Length (class)	F_3 Rachilla C. V. (class)	Classes for Length of Rachilla in Units of .1 mm. 14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		Means	Coefficient of Variabiilty
501–503	E. G.													5	18	11	10	5	1		50	25.900±0.118	4.78±0.32
504–506	G. 784				16	28	2	1													47	15.745±0.062	4.03±0.28
507–509	18–1–70–32	18	9.0		4	12	14	5	3												38	16.763±0.116	6.34±0.49
510–512	18–4–56–29	17	5.5		4	11	16	8	1												40	16.775±0.102	5.73±0.43
513–515	18–4–77–1	26	5.5										3	9	8	5	10	10	3	2	50	26.240±0.180	7.17±0.48
516–518	18–6–169–1	17	4.0			3	25	14	3												45	17.378±0.071	4.07±0.29
519–521	E. G.												3	6	10	21	10	1			51	25.627±0.109	4.50±0.30
522–524	G. 784			7	21	20	1														49	15.306±0.071	4.80±0.33
525–527	19–4–88–1	24	5.0								14	24	5	2	3						48	22.083±0.103	4.79±0.33
528–530	19–4–94–1	22	4.0							4	23	14	4	2							47	21.511±0.090	4.27±0.30
531–533	19–5–15–23	25	4.5							2	14	16	10	4							46	22.000±0.102	4.65±0.33
534–536	19–5–16–20	21	5.0						1	11	27	7	2								48	20.958±0.077	3.76±0.26
537–539	E. G.												3	12	15	10	10	2			52	25.346±0.120	5.07±0.34
540–542	G. 784			7	31	10	3	2													53	15.283±0.083	5.84±0.38
543–545	19–6–21–1	21	5.0					1	3	19	14	10	1								48	20.625±0.092	4.60±0.32
546–548	19–6–32–1	21	5.5			1	6	25	13	4		1									50	18.280±0.081	4.64±0.31
549–551	19–6–33–1	21	5.0					1	7	20	20	2									50	20.300±0.079	4.09±0.28
552–554	19–6–40–1	26	4.5									6	18	11	6	2	2	1			46	23.783±0.137	5.81±0.41
555–557	E. .G													5	16	9	5	1			36	25.472±0.111	3.87±0.31
558–560	G. 784			6	29	10	1														46	15.130±0.064	4.28±0.30

Bulletin 220 May, 1928

Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director
Morgantown

Certain Normal Characteristics of White Leghorn Females

AGRICULTURAL EXPERIMENT STATION STAFF

FRANK BUTLER TROTTER, A. M., LL. D. .... President of the University
N. J. GIDDINGS, Ph. D. .... Acting Dean and Director
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist (Soils)

T. E. Odland, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist (Soils)

D. R. Dodd, M. S.
Assistant Agronomist

M. M. Hoover, M. S.
Junior Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, M. S.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D.
Associate Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, B. A.**
Assistant Chemist

Leland Shriver
Assistant in Chemistry

DAIRY HUSBANDRY

E. L. Anthony, M. S. Agr.
Dairy Husbandman

H. O. Henderson, M. S. Agr.
Associate Dairy Husbandman

G. Malcolm Trout, M. S.
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

L. E. Dills, M. S.**
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

Paul A. Eke, Ph. D.
Assistant Farm Economist

F. D. Cornell, Jr., M. S.
Junior Farm Mechanician

W. W. Armentrout, M. S.
Junior Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M.
Home Economist

Hazel C. Cameron, M. S.
Research Specialist in Foods

Nell Nesbitt, A. M.
Research Specialist in Home Mgt.

HORTICULTURE

E. E. Knowlton, Ph. D.
Associate Horticulturist

H. L. Crane, M. S. Agr.
Associate Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

Ernest Angelo, M. S. Agr.
Junior Horticulturist

L. F. Sutton, B. S. Agr.‡
Assistant Horticulturist

H. P. Sevy, M. S. Agr.
Assistant in Horticulture

M. B. Hoffman, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

E. T. Wightman, M. S. Agr.
Junior Poultry Husbandman

RURAL SOCIOLOGY

T. L. Harris, Ph. D.
Rural Sociologist

ZOOLOGY

F. E. Chidester, Ph. D.
Zoologist

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*A Study of Certain Normal Characteristics of White Leghorn Females**

[PROGRESS REPORT]

In the development and improvement of the different breeds of poultry it is of first importance to have definite knowledge concerning the relationships between the different characteristics of the birds, for without this knowledge no intelligent program can be adopted. A breeder may need to know how he should proceed to decrease the variation in the size of the eggs laid by his fowls, or to increase or decrease the average size of the eggs, if that should be desirable. It is possible that problems of this nature can be more quickly and easily approached through a study of the normal relationships of the characteristics in the fowls than in any other way.

BIRDS USED AND GENERAL PLAN OF EXPERIMENT

The strain of Single Comb White Leghorns which was selected for this experiment had not been systematically bred so as to affect either the number, the size, or the variability in the size of the eggs laid. In fact, the fowls might well be considered a random sample of unimproved White Leghorns.

The general plan of the experiment was to select 200 pullets of this strain, feed them a laying ration which would be uniform during the course of the experiment, and keep a record during the life of the birds of their weight, the number of eggs laid, the weight of each egg, the date of laying, and the amount and kind of feed consumed by the flock per month. These data properly analyzed should afford information on the following points:

1.—The amount of variation in the mean or average weight of the different birds.

2.—The changes in the weight of laying hens from month to month and from year to year.

3.—The relationship between body weight and mean egg weight. In other words, the relationship, if any, between the size of the bird and the size of the eggs that she lays.

4.—The relationship between the size of the bird and the number of eggs that she lays.

*Submitted for publication March, 1927.

5.—The relationship, if any, between the size of the eggs and the number which a bird may lay.

6.—The relationship between the variations in the weight of the eggs which a bird lays and the number which she lays.

7.—The relationship between early sexual maturity and fecundity.

8.—The effect that the age of the bird has on the total annual weight of the eggs that she lays.

9.—The relationship, if any, between the mean decrease in the weight of the eggs in the cycles and the annual production.

This experiment was started November 1, 1925, when 200 Single Comb White Leghorn pullets were placed in small colony laying houses. The birds were hatched June 15 and had free range until they were placed in their winter quarters at which time their average weight was 2.62 pounds. This report covers the first year of the experiment.

General Directions

The following directions were adopted for carrying on this experiment.

GUIDE FOR WEIGHING AND FEEDING

1.—*Weighing Fowls:* Fowls to be weighed on the first day of each month. Weighing to be done early in the morning before the fowls are fed and the weight recorded to one-tenth pound.

2.—*Weighing Feed:* A record is to be kept of the total amount of feed consumed during each calendar month.

3.—*Weighing Eggs:* Eggs are to be weighed during the forenoon following the day on which they were laid. Weights to be recorded to one-tenth gram.

4.—*Feeding the Fowls:* Fowls are to be fed dry mash in hoppers and scratch feed in straw litter. Both the dry mash and the scratch feed are to be thoroughly mixed. The mash is to have the following composition:

Ingredients	Pounds
Bone Meal	50
Yellow Corn Meal (ground corn)	200
Ground Oats	100
Wheat Middlings, 16½% protein	200
Meat Scrap, 50% protein	75
Salt	6
Powdered Buttermilk	75

The scratch feed is to have the following composition:

Ingredients	Pounds
Yellow Corn	200
Wheat	100
Clipped Oats	100

Germinated Oats are to be fed during December, January, February, and March at the rate of 2 pounds dry oats per 100 fowls, per day. Oyster shell and limestone grit are to be given ad libitum.

The scratch feed is to be fed throughout the year at the following rates:

November	12 pounds per 100 fowls
December	12 pounds per 100 fowls
January	12 pounds per 100 fowls
February	12 pounds per 100 fowls
March	12 pounds per 100 fowls
April	10 pounds per 100 fowls
May	10 pounds per 100 fowls
June	8 pounds per 100 fowls
July	6 pounds per 100 fowls
August	6 pounds per 100 fowls
September	5 pounds per 100 fowls
October	5 pounds per 100 fowls

Broody Hens and Moulting: All broody hens are to be broken up as promptly as possible, and a record is to be kept of the individuals that become broody, length of time broody, the beginning of moult for each individual, and the length of moult.

Health of the Fowls

The health of the fowls during the year was good. There were twelve mortalities. Six birds were killed by dogs, accidents accounted for four more, and two deaths were attributed to weakness or disease. The following discussion of the results is based on the records made by the 188 birds remaining at the end of the year.

Weight of Birds

Table 1 gives the mean weight of the 188 birds on the first day of each month, the standard deviation in their weight, and the coefficient of variability.

TABLE 1.—Mean Weights of the Pullets Each Month, Standard Deviations in Their Weights, and Coefficients of Variability in Weights, From November, 1925, to October, 1926.

Months	Mean Weights in Pounds	Standard Deviations in Weights	Coefficients of Variability
November	2.62±.011	.224±.008	8.55±.30
December	3.08±.016	.328±.011	10.65±.37
January	3.34±.015	.303±.011	9.07±.32
February	3.37±.016	.335±.012	9.94±.35
March	3.49±.016	.329±.011	9.43±.33
April	3.47±.015	.307±.011	8.85±.31
May	3.57±.016	.318±.011	8.91±.31
June	3.67±.018	.369±.013	10.05±.35
July	3.68±.018	.365±.013	9.91±.34
August	3.70±.020	.409±.013	11.05±.38
September	3.75±.020	.411±.014	10.96±.38
October	3.76±.023	.476±.017	12.66±.44

From Table 1 it may be seen that the increase in the weight of the birds was relatively rapid during November and December. In January there was no significant increase; in February there was a slight gain; in March no significant change; but in April and May there was some further increase. During the remainder of the year the increase in weight was slight.

The standard deviation in the weight of the different birds increased considerably during the month of November. From the first of December till the first of May there was little change in the deviation in weight of the birds, but later in the season the variability in the weight of the birds increased slightly. If it should be shown, as now appears probable, that there is a significant positive correlation between the size of a bird and the mean weight of the eggs that she lays, then the deviation in the weight of a flock of pullets in the fall could be used as a measure of the variability in the weight of the eggs that they would lay later in the season. Hence, by selecting pullets of a uniform weight the variability in the egg weight would be kept at a minimum for any particular strain.

Table 2 gives the average weight of each bird based on the twelve weighings of each individual, and the number and average weight of the eggs laid by each bird.

TABLE 2.—Average Weights of the 188 Birds That Finished the First Year of the Test, Number of Eggs Laid, and Average Weight of the Eggs Laid by Each Bird.

Band Numbers of Birds	Average Weights in Pounds	Number of Eggs Laid	Average Weights in Grams
2	4.37	15	57.9
3	3.63	224	55.9
5	3.07	153	52.5
6	3.46	208	53.7
7	3.31	129	46.9
8	3.25	142	51.2
9	4.21	161	56.8
10	3.44	173	54.5
11	3.33	182	51.3
12	3.34	124	49.6
13	3.53	127	58.2
14	3.13	193	52.4
15	3.73	161	51.3
16	3.93	163	61.8
17	3.41	205	46.7
18	3.88	175	55.2
19	3.73	150	53.8
20	3.11	170	51.3
21	3.51	164	47.8
22	3.54	156	52.0
23	3.21	207	51.9
24	3.51	173	53.7
25	3.52	200	53.8
26	3.87	125	60.0
27	3.33	200	50.4
28	3.49	193	50.3
29	3.60	140	49.9
30	3.54	183	50.1
31	3.44	176	54.2
32	3.52	104	60.6
33	3.52	213	52.4
34	3.78	155	60.1
35	3.50	182	55.2
36	3.45	155	57.1
37	3.25	140	61.9
38	3.64	156	56.3
39	3.51	107	54.5
40	3.72	209	50.5
41	3.53	154	53.2
42	3.39	158	50.7
43	3.29	118	57.2
44	3.77	240	50.0
45	3.76	178	52.2
46	3.49	161	53.5
48	3.37	177	52.5
49	4.01	158	54.1
50	3.48	153	55.3

(Continued)

TABLE 2—Continued.

Band Numbers of Birds	Average Weights in Pounds	Number of Eggs Laid	Average Weights in Grams
51	3.31	205	49.9
52	4.09	186	59.1
53	3.90	211	50.8
54	3.48	206	58.1
56	3.16	157	54.1
57	3 83	147	53.9
58	3.83	105	56.9
59	3.48	148	51.3
60	3.32	163	49.3
61	3.90	173	56.2
62	3.46	195	56.8
63	3.92	26	59.5
64	3.88	194	54.4
65	3.47	213	54.5
66	3.33	208	48.7
67	3.43	227	52.4
68	3.35	120	56.0
69	3.41	176	53.3
70	3.70	182	50.6
71	3.92	225	56.5
72	3.62	56	50.2
73	3.58	182	56.0
74	3.64	215	54.6
75	3.81	224	53.3
76	3.54	48	49.5
77	3.18	203	49.6
78	2.95	36	48.0
79	3.76	170	55.9
80	3.04	195	51.1
81	3.46	149	55.3
82	3.47	216	55.2
83	3.27	235	50 3
84	3.20	227	51.2
85	3.63	165	59.6
86	3 28	123	56 0
87	3.37	168	55.1
88	3.05	188	53.2
89	3 48	206	52.9
90	3.36	150	53.5
91	3.47	167	53.5
92	3.21	166	52.7
93	3.41	181	54.0
94	3.48	190	57.5
96	3.89	208	60.2
97	4.07	170	51.9
98	3.43	184	54.7
100	3.30	189	55.0
101	3.27	204	52.4
102	3.53	54	55.2
103	3.46	123	53.8
104	3.08	182	49.7
106	3.49	173	58.4
107	3.39	124	53.4
108	3.48	213	50.3
109	3.80	233	51.7
110	3.60	202	55.7

(Continued)

TABLE 2—Continued.

Band Numbers of Birds	Average Weights in Pounds	Number of Eggs Laid	Average Weights in Grams
111	3.77	113	61.8
112	3.25	209	49.2
113	3.45	181	52.9
114	3.00	186	52.8
115	3.40	196	55.2
116	3.69	155	53.1
117	3.35	143	49.6
118	3.08	172	50.0
119	3.53	191	58.1
120	3.82	169	54.8
121	3.20	166	55.0
122	3.41	176	54.6
123	3.78	213	59.9
124	3.41	199	53.6
125	2.97	143	54.8
126	2.84	236	47.1
127	3.25	221	47.7
128	3.83	102	56.9
129	3.38	182	51.6
130	3.40	203	52.0
131	2.99	204	51.9
132	2.87	207	49.9
133	3.13	134	51.6
134	3.41	201	56.0
135	3.60	201	54.8
136	3.66	227	53.7
137	3.68	140	53.5
138	3.16	190	53.7
139	3.72	99	52.9
140	3.28	169	49.4
141	3.87	137	54.4
142	3.48	18	51.0
143	4.09	173	53.6
144	3.95	178	50.1
145	3.77	118	57.8
146	3.26	195	50.5
147	3.59	175	56.6
148	3.44	188	54.2
149	3.73	163	56.6
150	3.10	212	46.3
151	3.49	179	56.8
152	3.55	176	47.7
154	3.16	106	51.1
155	3.45	143	54.4
156	3.84	189	56.5
157	3.64	171	52.1
158	3.40	143	52.6
159	3.78	194	47.8
160	3.15	166	48.0
161	3.54	140	52.3
162	3.27	145	54.3
163	3.05	157	44.9
164	3.73	172	49.2
165	3.02	150	47.6
166	2.97	113	47.0
167	3.33	185	52.9

(Continued)

TABLE 2—Concluded.

Band Numbers of Birds	Average Weights in Pounds	Number of Eggs Laid	Average Weights in Grams
168	3.14	169	53.1
169	2.93	140	48.6
170	3.60	195	54.2
171	3.08	109	50.2
172	3.41	141	53.0
173	3.43	158	53.6
174	3.02	182	51.2
175	3.48	228	50.1
176	3.93	168	57.5
177	3.31	170	53.0
178	3.17	181	54.7
179	3.56	207	54.8
180	3.10	166	50.9
181	3.17	216	52.8
182	3.60	140	54.1
184	3.24	220	54.6
185	3.43	110	51.8
186	3.47	199	55.6
187	3.21	149	45.8
190	3.37	126	54.3
191	3.20	157	54.8
192	3.56	230	49.8
193	3.30	125	54.5
194	3.10	189	49.7
195	3.60	161	53.8
196	3.00	180	53.0
197	3.38	230	52.9
198	3.42	183	55.5
200	3.28	143	57.6

The mean weight of the birds, based on the average weight of each individual, was $3.46 \pm .013$ pounds; the standard deviation of the average weights of the birds was $.274 \pm .010$; and the coefficient of variability was $7.92 \pm .27$. These figures probably represent with a fair degree of accuracy the variability in weight of an unselected strain of White Leghorn pullets.

The total number of eggs laid by the 188 birds was 31,682. Forty-five birds laid 200 or more eggs each, while only eight birds laid fewer than 100 eggs each. The production ranged from a maximum of 255 eggs in the case of bird 83 to a minimum of 15 for bird 2. The average egg weight varied from a maximum of 61.9 grams for bird 37 to a minimum of 44.9 grams for bird 163. The average weight of all the eggs laid during the year by the 188 birds, including the eggs (4.6%) laid outside the trap nests, was 53.09 grams.

Due to the immaturity of the pullets the production during the winter months was low as shown in Table 3, but with the beginning of spring the production materially increased, reaching a maximum in May with an average daily production of 144.13 eggs from 188 birds,

TABLE 3.—Number of Eggs Laid During Each Calendar Month by the 188 Birds, Average Weight of Eggs, Average Number of Eggs Laid Daily, and the Average Number Laid per Bird per Month, From November, 1925, to October, 1926.

Months	Total Number of Eggs Laid	Average Weights of Eggs in Grams	Average Number of Eggs Laid Daily	Average Number Eggs Laid Per Bird Per Month
November	71	39.23	2.37	.38
December	1148	42.80	37.03	6.11
Tanuary	1397	46.58	45.06	7.44
February	1402	49.66	50.07	7.46
March	3323	51.96	107.19	17.68
April	4159	53.56	138.63	22.12
May	4468	53.39	144.13	23.77
June	4014	54.08	133.80	21.35
July	3928	54.13	126.71	20.89
August	3646	54 45	117.61	19,39
September	2646	56.17	88.20	14.07
October	1480	57.28	47.74	7.87

or a production of 76.7 percent. The average production per bird for the year was 168.52 eggs, which is reasonably good for a strain of fowls that had not been bred for high fecundity.

With a very slight exception in the month of May, the average egg weight increased from the beginning of the laying year to its close. This increase was especially great during December, January, February, March, and April. During the next four months there was little change, but during the last two months the eggs increased in weight on an average of more than one gram each.

If eggs weighing two ounces each, or about 56 grams, are most desirable for commercial purposes, then the eggs laid by this flock were much too light during the first half of the laying year, and the problem of how to increase the average size of the eggs laid by pullets during the fall and early winter months without materially increasing the size later in the season is worthy of careful study.

It is desirable to produce eggs of uniform size, hence it is important to know the degree of variability in the weight of the eggs laid by the birds in an unselected strain. This variability expressed as the standard deviation in the average annual egg weights for the 188 females amounts to $3.30 \pm .11$ grams, with a coefficient of variability of 6.2 percent. This standard deviation in the average egg weights corresponds closely with the figures reported by the author in Bulletin 195 of this Station.

The relationship between the size of a fowl and the size of the eggs that she lays is important, for, if such relationship does exist, it affords the poultryman an easy and direct method of quickly modifying the

size of the eggs should this be desirable to meet market requirements. To throw some light on this condition, the coefficient of correlation has been calculated, using the average body weight and average egg weight of the 188 birds under discussion. The coefficient thus derived is $+.459 \pm .039$. This is clearly significant as the coefficient is almost twelve times the probable error. These results agree with those shown by the author in Bulletin 195, and the conclusion seems justified that the heavier birds in a flock lay the heavier eggs.

The relationship between the number of eggs that a bird will lay dependent on whether they are large or small is also important to a producer.

The coefficient of correlation between the number of eggs laid by the different birds and the average weight of the eggs laid by the same birds is $-.136 \pm .048$. As this coefficient is less than three times its probable error, the evidence indicates that there is no relation between the number of eggs laid by a bird and the average size of the eggs. This result, too, is in agreement with the earlier findings of the author reported in bulletins 182 and 195 of this Station.

In breeding to increase the egg production of a flock, it is equally as important to decrease the number of very poor layers as it is to increase the production of the better layers, hence it is of value to have data on an unselected strain showing what may be designated as the normal variability in respect to the number of eggs laid by the various females. The standard deviation in the number of eggs laid has been calculated and has been found to be 41.52 ± 1.44. This is a high deviation and shows that there was a very material variability in the number of eggs laid by the birds in the flock.

As to whether the heavier birds of this flock laid as many eggs as their smaller companions, the coefficient of correlation between the weight of the birds and the number of eggs laid has been found to be $-.159 \pm .047$. This coefficient is not significant, as it is only about three times its probable error, and consequently as far as these data go the smaller birds of this flock laid equally as well as the larger ones.

The pullets that develop fastest during the summer and lay first in the fall should have a better opportunity to make a good egg record during the first laying year than their companions that begin to lay later in the season. It is possible, nevertheless, that the birds that develop more slowly will lay more steadily after they begin to lay and hence make as good or better records than those that begin to lay earlier in the season. In order to study this matter the coefficient of

correlation was calculated between the age in days when each female laid her first egg and the number of eggs laid during the first year by each bird, and found to be −.403±.041. This coefficient is significant as it is about ten times its probable error and is negative. In other words, the older the pullet before beginning to lay the fewer eggs did she lay during the first laying season. This relationship gives the poultryman an easy and reliable method of culling his pullets in the fall so as to increase the egg production during the first laying year. Whether this relationship holds true during succeeding years remains for future experiments to determine.

The mean age of laying the first egg was 198.05±1.69 days and varied from a minimum of 152 days to a maximum of 310 days. The standard deviation of the age of the birds in days when they laid the first egg was 34.4 days. This deviation is considerably larger than that reported by the author in Bulletin 182, for White Leghorn pullets. This large deviation is probably due to the fact that the birds in this experiment were late hatched and those that were somewhat backward about starting to lay in the fall were delayed by the cold weather of winter so that they did not begin to lay until the advent of spring thus materially increasing the deviation in the age of laying.

It appears that the standard deviation in the age of laying the first egg is a very valuable criterion by which to determine the success of breeding and management. In a flock of pullets properly bred and properly reared, all the birds should begin to lay at about the same time in the fall thus giving evidence of uniformity in breeding and development.

To throw light on the question as to whether or not the heavier birds mature at a younger age and begin to lay earlier in life than their smaller companions, the coefficient of correlation between the average weight of each bird and her age in days when laying her first egg was calculated, and found to be +.003±.049. As this coefficient is not significant, being only one-fifteenth as great as its probable error, the evidence indicates that there is no relation between the size of the bird and the age at which she begins to lay.

Tables 1 and 3 show that there was a progressive increase in the weight of the birds and also a similar increase in the weight of the eggs from month to month. The coefficient of correlation between the monthly weight of the birds and the monthly weight of the eggs was calculated and found to be +.996±.013, showing that the increase in body weight and the increase in egg weight go closely hand

in hand, at least during the pullet year. This relationship is also shown clearly by Figures 1 and 2. Figure 3 shows the mean egg production for each month of the year.

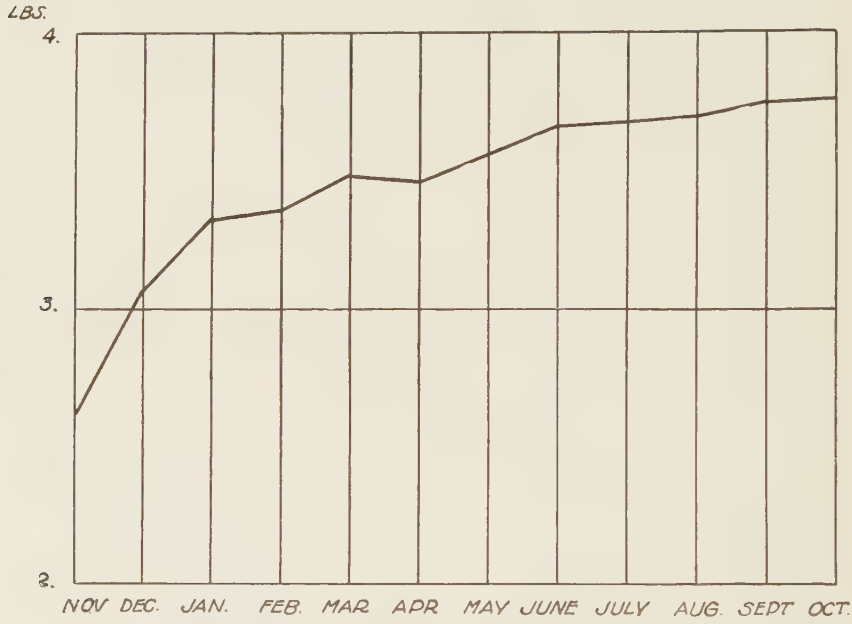


Fig. 1—Mean monthly weights of birds.

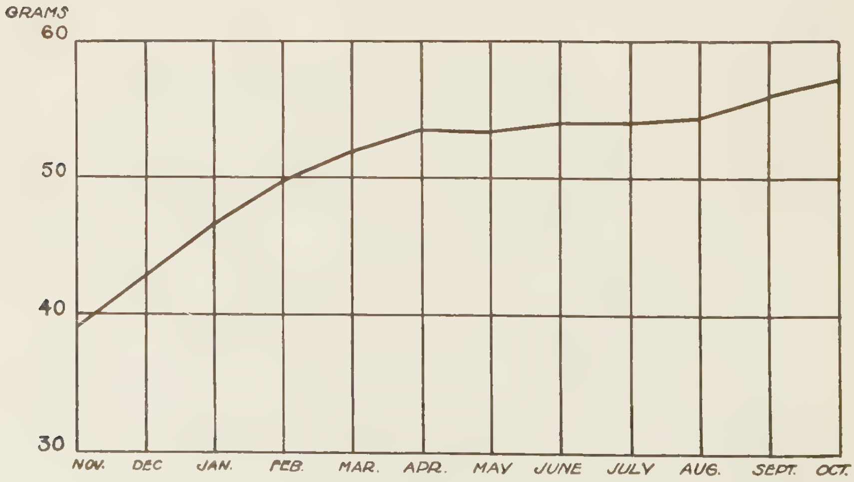


Fig. 2—Mean monthly weights of eggs.

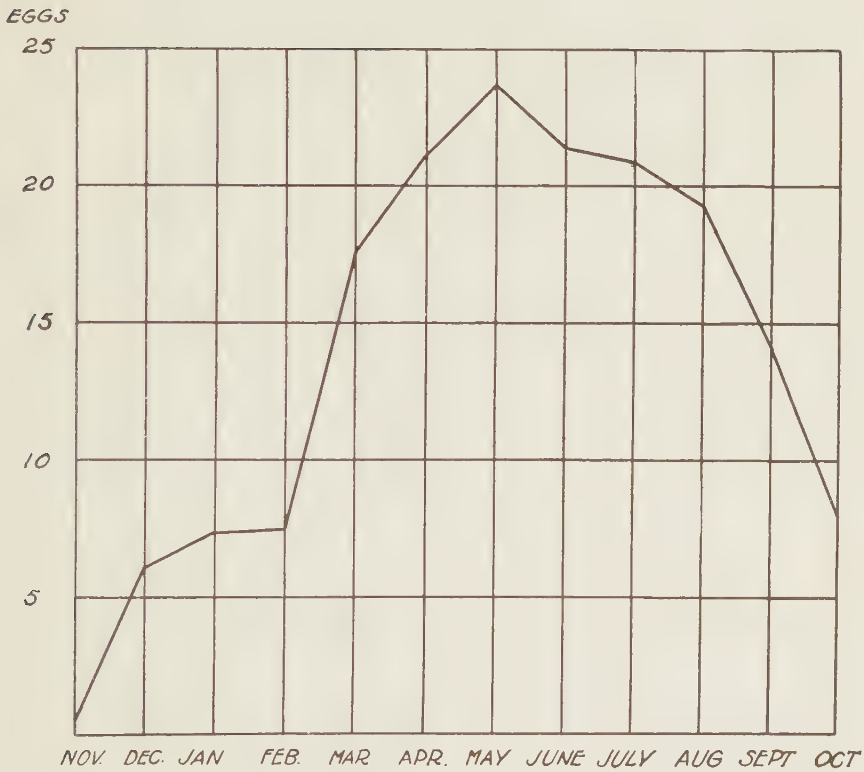


Fig. 3—Mean egg production per month.

SUMMARY

In this bulletin is discussed the record of 188 Single Comb White Leghorn pullets during their first laying year, or from October 31, 1925, to November 1, 1926.

During the year all of the eggs that were laid were weighed individually and the weight recorded to one-tenth gram. Each bird was also weighed monthly.

1.—The average weight of the different birds ranged from a minimum of 2.84 pounds to a maximum of 4.37 pounds. The mean weight of the birds at the beginning of the year was 2.62 and at its close 3.76 pounds.

2.—The egg production ranged from a minimum of 15 eggs to a maximum of 255. The average production for the year was 168.52 eggs. Eight birds laid fewer than 100 eggs each, while forty-five laid 200 or more.

3.—The average weight of the eggs laid by the different birds ranged from a minimum of 44.9 grams to a maximum of 61.9 grams. The mean weight of all eggs laid during the year was 53.09 grams.

4.—Based on the eggs laid in the trap nests, forty-seven birds each laid during the year a total weight of ten thousand grams or more or eggs.

5.—With but slight exceptions, the average size of the eggs increased from the beginning of the year to its close.

6.—The heavier birds laid the heavier eggs.

7.—There was no relation between the number of eggs laid by a bird and the size of the eggs.

8.—There was no relation between the size of the bird and the number of eggs that she laid.

9.—The birds that were youngest when beginning to lay laid more eggs during the first year than did their companions that matured more slowly.

10.—There was no relation between the average size of a bird and her age when reaching sexual maturity.

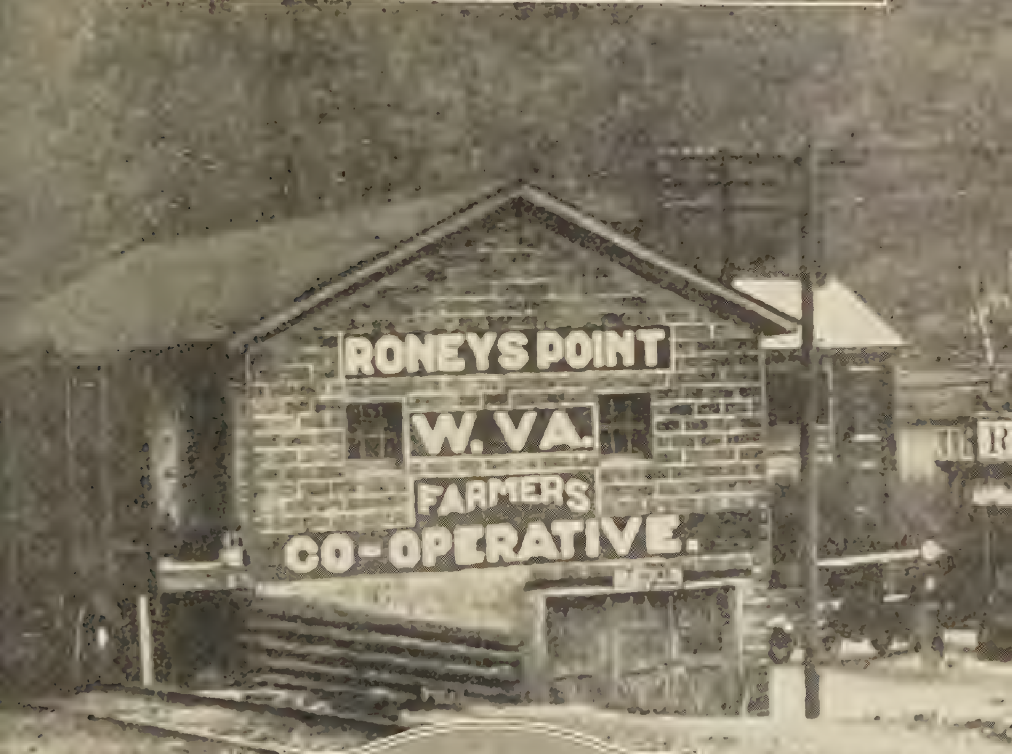
11.—The increase in the weight of the birds and the increase in the mean weight of the eggs were closely related throughout the year.

Bulletin 221

March, 1929

Cooperative Buying in West Virginia

by Paul A. Eke



Including W. Va. Cooperative Marketing Act of 1923

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. .... President of the University
F. D. FROMME, Ph. D. .... Dean and Director
WALTER C. SCHNOPP, B. S. Agr., ... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D. — Agronomist and Geneticist
E. P. Deatrick, Ph. D. — Associate Agronomist (Soils)
W. H. Pierre, Ph. D. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist (Soils)
D. R. Dodd, M. S. — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
J. H. Longwell, M. A. — Assistant Animal Husbandman
J. H. Rietz, D. V. M. — Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
L. P. Hansen, Ph. D. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
Leland Shriver, B. S. — Assistant in Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D. — Dairy Husbandman
L. M. Thurston, Ph. D. — Assistant Dairy Husbandman
K. S. Morrow, M. S. — Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr. — Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
Edwin Gould, B. S. Agr. — Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
Paul A. Eke, Ph. D. — Assistant Farm Economist
F. D. Cornell, Jr. M. S. — Assistant Farm Mechanician
W. W. Armentrout, M. S. — Assistant Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M. — Home Economist
Hazel C. Cameron, M. S. — Research Specialist in Foods
Nell Nesbitt, A. M. — Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D. — Associate Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
M. B. Hoffman, M. S. — Assistant in Horticulture
W. N. McCubbin, M. A. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Associate Plant Pathologist
L. H. Leonian, Ph. D. — Associate Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman
T. B. Clark, B. S. Agr. — Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡Assigned to the Reymann Memorial Farms, Wardensville, W. Va.

CONTENTS

Purposes of Farmers' Warehouses

To supply guaranteed high quality products.

To stabilize retailers margins in competitive territory.

Purposes Can Be Accomplished Best By

Fitting the services rendered to the demands and needs of the community.

Incorporating the business under the Cooperative Act of the State.

Providing sufficient capital.

Paying a fixed and nominal rate of interest on the capital stock.

Setting aside an adequate reserve fund.

Rebating regularly on the basis of patronage any remaining net profits of the business.

Handling supplies which are demanded in volume.

Handling supplies of known origin and guaranteed quality.

Buying supplies on the prevailing market when in demand.

Selling supplies at reasonable competitive prices.

Conducting the business on a cash basis.

Employing a competent well-liked manager.

Keeping an adequate system of accounts.

Cooperative Buying in West Va.

Cooperative buying has resulted in several notable improvements in the business of furnishing commodities to the farmers of West Virginia. The most significant improvements have been: First, *a supply of guaranteed high quality products*, and second, *a downward revision of the retailing margins.* Both improvements have been so advantageous to the cooperators as to set these factors up as the major purposes of the whole movement.

It is, perhaps, needless to say that these purposes should be accomplished with the minimum expenditure of both money and energy.

Experience in West Virginia has demonstrated that the purposes enumerated can be attained in many counties through simple car-door purchasing. In other counties a warehouse has accomplished them to better advantage. But even where warehouses are being operated, those warehouses which have been operated on a conservative and as nearly as possible cash basis have been in a position to accomplish these purposes much better than those doing a much larger business on a system of credit, with cut-throat prices, and extravagant services.

The real saving to the members has consisted in having a constant supply of high quality products, reasonable retailing margins, and rebates to patrons. Furthermore, patrons of non-cooperative feed stores have indirectly benefited through reduced retail margins and improved quality of supplies.

The accompanying map (Figure 1) shows the counties in which the Farm Bureau buying activities have been studied.

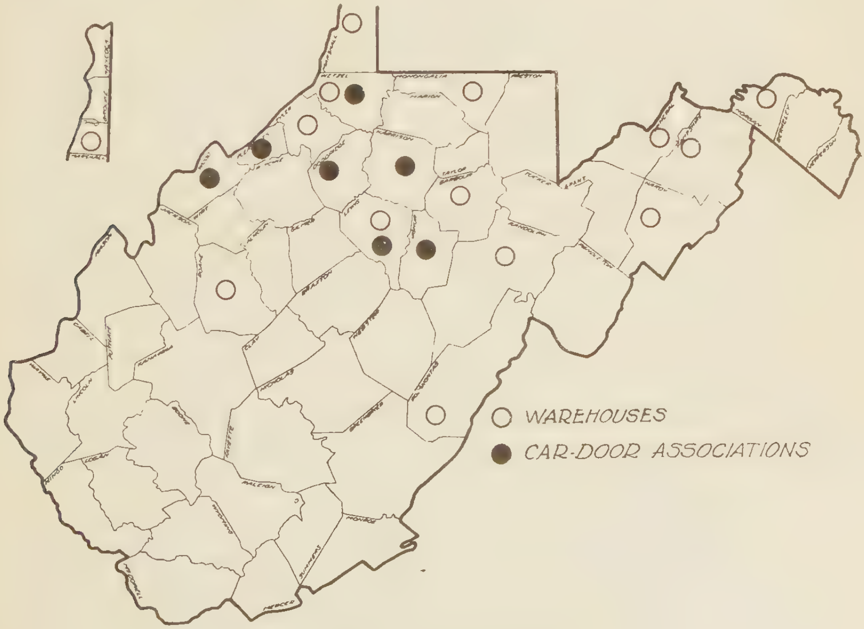


Fig. 1.—Location of the cooperative associations studied.

A study of the organizations, business practices, and difficulties of each organization has been helpful in discovering the problems common to all, and in many instances has pointed the way to their solution. This study was carried out between October 1, 1925, and January 15, 1926. A detailed schedule was filled out for each of the twenty organizations through visits to the places of business, examination of records, and interviews with county agricultural agents, farm bureau officers, and directors and managers of the various warehouses and car-door associations.

PRELIMINARY SURVEY

Before beginning any cooperative buying, either as a warehouse or car-door association, a careful and unprejudiced survey should be conducted by a reliable person or by a committee. This survey should determine, insofar as possible, the economic needs and desires of the prospective patrons. For purposes of arriving at correct decisions, the need of adequate information cannot be over-emphasized.

The preliminary survey may take the form of a number of meetings at which the readiness of the community for this kind of a business will be discussed. It may be well for the committee to call on the prospective members individually and learn the attitude of each toward the business as well as his prospective patronage. Any available records or statistics dealing with the local supply business may be consulted with profit.

From the facts revealed by this survey, decisions can be made as to the feasibility of beginning a business, the kind of organization to establish and the kind of services to extend.

Starting Business

Before starting operations local conditions should be very carefully observed, keeping firmly in mind the conditions which are absolutely necessary to the success of a cooperative business. The prospective volume of business will come

TABLE 1.—Length of Time Which Various County Farm Bureaus in West Virginia Operated as Car-Door Associations and Warehouses Prior to December 31, 1925.

Warehouse Number in the Order of the Date of Beginning Business	Length of Time Operated as a Car-Door Association Before Warehouse Business was Begun	Length of Time the Warehouse Business was Conducted Prior to December 31, 1925
1	none	7 years
2	no data	4 years
3	10 years	3 years
4	5 years	2 years 6 months
5	5 years	2 years 4 months
6	3 years	2 years 3 months
7	1 year	2 years 1 month
8	4 years	2 years
9	1 year	1 year 8 months
10	5 months	11 months
11	8 years	11 months
12	5 years	11 months
13	5 years	10 months
14	5 years	4 months
15	3 years	3 months

A humble beginning is often desirable for a cooperative warehouse. Note the discussion on pages 24 and 25.

in for primary consideration from the following points of view: (1) The supplies that the prevailing type of agriculture in the trade territory demand. (2) The quantity of these essential products that are shipped in from other sections, and during what seasons of the year (This information can often be obtained from the records of the railroad freight station). (3) The competitors in the field and the economic needs due to unsatisfactory quality of commodities and service, and unreasonable retailing margins. (4) A sufficient number of farmers willing to buy their supplies on the cooperative plan.

Other factors to be considered are the willingness and ability of the farmers to manage and finance the undertaking. Much of the foregoing information can best be obtained by personal interviews, and by free discussions at group meetings.

If a sufficient volume of business, sufficient capital, and efficient managerial ability are assured, steps may be taken in the organization of a cooperative business.

Type of Organization

After the decision to start a cooperative business, the next step is to determine what type of organization will best serve the purpose. The potential volume of business, the willingness and ability to provide finances, and the grade of service for which the patrons are willing to pay, are the deciding factors in determining whether a warehouse or car-door organization will be most desirable. In this connection it is well to bear in mind that car-door buying has served as an apprenticeship for thirteen of the fifteen warehouses under consideration. Table 1 shows that the various county farm bureaus conducted car-door buying operations for a period ranging from one to ten years, with the exception of two bureaus which operated less than one year, before warehouse businesses were organized.

Renting an available building may be more economical than building or buying a warehouse. Refer to discussion on pages 24 and 25.

Experience in the state, as shown in Tables 2 and 3, indicates that a car-door business is an elastic business which can be adapted to handling but a few carloads a year, or may be developed to handle a business of several carloads per month. For the five counties studied in Tables 2 and 3, the number of cars handled for the year ranged from 11 to 72.

TABLE 2.—Number of Carlots Handled by Five West Virginia County Farm Bureau Car-Door Associations for the Fiscal Year Prior to the Time of This Survey.

Car-Door Association Number in the Order of the Date of Beginning Business	Volume of Business in Carloads				
	Total	Feed and Flour	Fertilizer	Salt	Lime
1	72	33	12	3	24
3	53	19	15	1	18
5	23	15	7	No data	1
7	18	11	1	3	3
4	11	4	3	1	3

TABLE 3.—Value of Commodities Purchased by Five West Virginia County Farm Bureau Car-Door Assocations for the Fiscal Year Prior to the Time of This Survey.

Car-Door Association Number in the Order of the Date of Beginning Business	Value of Commodities Purchased by the Car-Door Associations for the Fiscal Year
1	$47,292.50 (11 months)
2	25,000.00
4	20,000.00
5	15,000.00
3	7,000.00

TABLE 4.—Number of Carlots Handled by Eight West Virginia County Farm Bureau Warehouses for the Last Fiscal Year Prior to the Time of This Survey.

Warehouse Number in the Order of the Date of Beginning Business	Volume of Business in Carloads				
	Total	Feed and Flour	Fertilizer	Salt	Lime
7 (10 months)	110	63	14	3	30
9	87½	57	16	½	14
4	44	16	18	1	9
6	37	27	2	7	1
10 (7 months)	36	11	15	1	9
1	28	3	19	2	4
8 (11 months)	22	20	2	No data	No data
12 (10 months)	15	7	6	No data	2

TABLE 5.—Value of Commodities Sold by Eleven West Virginia County Farm Bureau Warehouses for the Fiscal Year or Fraction of Year for Which Data Were Available at the Time of This Survey.

Warehouse Number in the Order of the Date of Beginning Business	Value of Commodities Sold By the Warehouses
3	$112,000.00
9	101,952.44
7	77,083.57
6	52,578.75
4	41,500.00
8	40,936.63
10	35,000.00 (7 months)
5	26,000.00
12	18,000.00 (6 months)
13	12,000.00 (8 months)

A successful warehouse must have a certain minimum volume of business because of the constant overhead expense. Tables 4 and 5 give the volume of business of several warehouses in the state in terms of carloads and in the value of the commodities handled during the year prior to the study, and the average value of commodities purchased per month for the same period. The range in the value of the annual business has been from about $18,000 to slightly more than $100,000. The number of carloads handled ranged from 15 to 110. A careful study of these warehouses indicates that with the usual conditions prevailing a minimum annual business of from $35,000 to $50,000 is necessary in order to (1) carry the overhead expense; (2) keep an adequate stock of supplies; (3) pay a reasonable dividend on the capital stock; and (4) keep the retailing margins down to a competitive and reasonable level.

If a sufficient volume of business can be obtained for either a car-door or warehouse business, the choice between the two types of organizations must be based on:

(1) A willingness of the patrons to pay the greater costs of conducting a warehouse service.

(2) The willingness and ability of the patrons to finance a warehouse if it is chosen.

(3) The possibility of obtaining capable warehouse management.

A number of local conditions may greatly influence the foregoing factors.

One of the most important is the location and condition of the roads. Three general conditions have been observed in the counties studied.

(1) Counties with good roads radiating from a common center have found a warehouse business possible.

(2) Counties with good roads but having several small trade centers which are rather inaccessible from a central point have found a car-door business more suitable than a warehouse.

(3) Counties with poor roads where patrons are far from a central point have found both types or organization difficult and expensive. Where volume of business is small some opportunity for temporary storage seems to be nesessary. This system of temporary storage has in most cases been the source of much misunderstanding and some financial loss.

The customs and usual practices of the patrons must also be ascertained. Custom is often a good indicator of what type of service will satisfy a sufficient number of patrons. Savings made by limiting the usual services are often effective in changing these customs. This has been shown by the fact that the more successful warehouses are doing a large business almost entirely on a cash basis in spite of the customary extension of credit by competitors. Car-door buying has resulted in sufficient savings to induce a large number of farmers to accept this limited service in preference to the more complete service offered by cooperative or non-cooperative supply stores. Some of the better organized counties in the state prefer the car-door business because of the lower costs.

ORGANIZATION

If the committee in charge of the preliminary survey finds that there are actual economic needs, necessary competitive advantages, and a general willingness on the part of the farmers to organize and patronize a cooperative supply business, organization meetings will be in order.

Organization meetings widely advertised and well planned will aid materially in accomplishing the important business which is to be considered. The future success or failure of the enterprise will depend to a very large extent upon the judgment exercised at these meetings. Such matters as (1) incorporation, (2) by-laws, (3) financing, (4) business site, (5) business plan, and (6) selection of a manager, require the best talent and experience which are available.

It will prove helpful to consult a specialist in cooperative business methods prior to the organization meetings and it may be advisable to have a specialist present at the meeting to answer technical questions with regard to cooperative organization, legal matters, and business practices. Help can often be obtained free of charge by applying to the College of Agriculture, Morgantown, or the West Virginia Farm Bureau, Clarksburg, West Virginia.

First Meeting

After assembling, and a presiding officer has been selected, the following is a suggested order of business:

1. Members of the preliminary survey committee shall state their findings and present recommendations based on these findings. At least two recommendations should be given at this time: (1) the desirability of organizing a

Delivering supplies by truck is convenient in the large city dairy districts. **Refer to discussion on pages 27 and 28.**

supply business, and (2) if desirable to organize, whether a car-door or warehouse company is more desirable. These recommendations should be fully discussed and a vote taken. The committee may go farther at this time in its recommendations, but care must be exercised in not bringing in too many details which will come logically in the second meeting after other committees have had an opportunity to complete their work. The recommendations offered and the votes taken should be carefully recorded by by a temporary secretary.

2. If a decision is made to start a car-door business steps may then be taken to perfect an organization for the promotion of this type of service in the county. Many communities have been organized as unincorporated associations to conduct a car-door business. The County Farm Bureau has often taken the responsibility for this work and has appointed or elected a county purchasing agent and also encouraged the selection of community purchasing agents. If a separate county organization is desired, however, a committee should be appointed to prepare articles of incorporation and by-laws. The model by-laws given on pages 15 to 18, will serve the purposes very well, and may be adopted by vote of those present at the meeting. In case the model by-laws are adopted, a tentative board of directors may be elected at this time. This board can then take charge of the incorporation of the company, election of a permanent board of directors, and carry out other provisions necessary to begin business operations. In case other by-laws are desired, a committee can be appointed to draw up the by-laws and a second meeting called for discussions and adoption. Complete organization may then be carried out as previously stated.

When the company is fully organized the board of directors will take full charge of the promotion of the car-door service in the county.

3. If it is decided that a warehouse business is to be promoted, three committees should be appointed to take care of the details or organization.

(a) A committee on incorporation and by-laws.

(b) A committee on financing, stock subscription, and membership.

(c) A committee on business site and business facilities.

4. At the first meeting a rather complete discussion of cooperative principles and the state cooperative act by a specialist in cooperative business methods is very desirable. At the conclusion of this discussion a vote may be taken to determine the will of the members in respect to incorporating under the state cooperative act. It may be desirable, however, to defer the vote until the committee on incorporation has had an opportunity to be thoroughly informed with regard to the merits of the act, and of other alternatives.

Second Meeting

After the three committees appointed at the previous meeting have had an opportunity to develop carefully worked out plans of procedure, a second meeting may be called to discuss the proposals and to vote upon them. If a large number of prospective members are present, it is desirable to adopt tentative by-laws, as recommended by the committee, and to elect a tentative board of at least 5 and preferably 10 directors. This action with regard to directors and by-laws will not be binding but should be considered as carefully as if the action were final, for it will be expected that the persons who act later as incorporators and who then go through the form of legally adopting the by-laws and electing directors will follow the actions taken by the larger body of prospective members. A small body of incorporators can carry out the formal organization, including incorporation, adoption of by-laws, and election of the first directors, with more dispatch and smaller expense than can be done by a larger body of members where conditions are not always favorable to deliberate and orderly procedure. The first permanent board of directors, as soon as elected, shall proceed to the subscription of capital, the acquisition of the business site and facilities, the selection of a manager, and in general to the establishment of business operations.

A tentative subscription list may be circulated at this meeting on which is shown the names of the prospective members and the amounts of capital which each prospective member will subscribe.

Incorporation

A cooperative business which requires a large fixed capital or entails large financial obligations should by all means be incorporated. The following are the most outstanding advantages of incorporation:

1. Limits the personal liability of the members.

2. Permits the association to hold and transfer title to property of all kinds including land.

3. Gives the association a standing in court proceedings for the collection of claims and damages.

4. Gives the association a better standing in the community.

5. Adds stability to the organization and provides for its continuance over an indefinite period.

A cooperative business which is not incorporated has the following disadvantages:

1. Each member is jointly and severally liable for all obligations of the association.

2. The association cannot sue except in the names of the individual members or in the name of a person duly empowered, and if it is made a defendant in a suit only those members served with process are held.

3. The association cannot take, hold, or convey real estate by its association name.

4. The association lacks permanency, stability, responsibility, and business standing.

The Articles of Incorporation should be carefully worked out by a committee who will consult the requirements set forth in Section 6 of the State Cooperative Act. (See pages 47 and 48.)

The provisions set forth in the model by-laws on pages 15 to 18 (if these by-laws are adopted) should be followed closely in complying with the provisions of the law just referred to. If by-laws differing from the model by-laws suggested in this bulletin are desired, a specialist in cooperative organization and business practice should be consulted in the formulation of such by-laws, in order that they may conform with tested cooperative principles and practices. Furthermore, it is advisable to submit the newly formulated by-laws to a lawyer who will see that they conform to the State Cooperative Act before Articles of Incorporation based on these by-laws are adopted.

By-Laws

A good form of by-laws must have the following characteristics:

1. All provisions must conform with the State Cooperative Act.

2. The by-laws should conform with cooperative principles and the best business practices.

3. All provisions should be adapted to the needs of the particular type of business carried on by the company.

4. Some provisions may be specifically designed to meet particular local conditions.

To facilitate the adoption of legal, workable, and safe by-laws, a model form of by-laws is here submitted. These by-laws have been carefully worked out and conform with the State Cooperative Law, as it existed at the time this bulletin was published.

These by-laws are in a large part the results of a study of the experiences of more than a dozen warehouses and half as many car-door associations in West Virginia, during periods ranging from a few months to more than seven years.

The model by-laws included may save a good deal of work on the part of the incorporators and also perhaps save the company from the embarassment of a faulty organization. Originality on the part of the organizers has no merit in the adoption of by-laws for a business in which the organizers have had no opportunity for wide experience.

When changes are desirable or necessary, they should be carefully reviewed by a specialist in cooperative business methods. It is not safe to conduct a business with by-laws which have not been submitted to men with training and experience in cooperative organization because (1) the by-laws may be illegal, (2) may provide for an unwise financing plan, (3) may be unfair and unjust to certain patrons and stockholders, (4) may result in loss of control of the company by the members and patrons. These are but a few of the difficulties encountered by some of the farmers' warehouses which have been organized in West Virginia.

Tables 6 and 7 show that there has been an attempt by the warehouses to apply cooperative principles with regard to voting and stock ownership even though most of the companies have not been incorporated under the State Cooperative Act. Several companies allow one vote for each share of common stock, relying for well distributed control on limitations placed on the number of votes allowed each person. There is always danger of a company which votes on the basis of stock ownership getting under control of a few men who will run it for their own profit instead of for service to the patrons. Such has been the experience of two companies listed in this study.

TABLE 6.—Systems of Control Employed by 14 West Virginia County Farm Bureau Warehouses.

Warehouse Number in Order of Date of Beginning Business	System of Control of Voting Power	Number of Shares of Stock Authorized	
		Common	Preferred
1	Each Farm Bureau Member One Vote	Unincorporated	Unincorporated
2	Each Shareholder One Vote	Unincorporated	Unincorporated
3	Each Common Stockholder One Vote	No data	No data
4	Each Common Stockholder One Vote	226	None
5	Each Common Stockholder One Vote	220	None
6	Each Share of Common Stock One Vote[1]	1,000	None
7	Each Share of Common Stock One Vote[2]	2,000	None
8	Each Share of Preferred Stock One Vote[3]	72	2,500
9	Each Preferred Stockholder One Vote	1,000	90
10	Each Share of Common Stock one Vote[2]	1,000	None
11	Each Share of Common Stock one Vote[2]	600	None
12	Each Farm Bureau Member One Vote	No Stock	No Stock
13	Each Farm Bureau Member One Vote	Unincorporated	Unincorporated
14	Each Common Stockholder One Vote	500	No data

(1) Maximum number of votes by one person, 10
(2) Maximum number of votes by one person, 40
(3) Maximum number of votes by one person, 50

TABLE 7.—Limitations Provided in the By-Laws With Regard to Dividends and Stock Ownership for 14 West Virginia Warehouses.

Warehouse Number in Order of Date of Beginning Business	Maximum Rates of Annual Dividends on Capital		Largest Percentages of Total Authorized Capital Stock Which One Person is Permitted to Own	
	Common	Preferred	Common	Preferred
1	Unincorporated	Unincorporated	Unincorporated	Unincorporated
2	Unincorporated	Unincorporated	Unincorporated	Unincorporated
3	3 percent	6 percent	No data	No data
4	No limit	No stock	½ of 1 percent	No stock
5	6 percent	No stock	100 percent	No stock
6	6 percent	No stock	1 percent	No stock
7	No limit	No stock	2 percent	No stock
8	No stock	6 percent	No stock	2 percent
9	No stock	6 percent	1/10 of 1 percent	100 percent
10	6 percent	No stock	2 percent	No stock
11	6 percent	No stock	6⅔ percent	No stock
12	No stock	No stock	No stock	No stock
13	Unincorporated	Unincorporated	Unincorporated	Unincorporated
14	No stock	6 percent	1/5 of 1 percent	No stock

Any company incorporated under the general incorporation act can by a simple majority vote of the stock wipe out all cooperative features contained in the by-laws. This cannot be done so easily when incorporated under the State Cooperative Act, because the cooperative features are a part of the Articles of Incorporation; and a two-thirds vote of the directors in addition to a majority vote of all the members is necessary to amend the articles. Moreover, to change property rights and interests a three-fourths vote of all the members is necessary.

SUGGESTED BY-LAWS FOR A COOPERATIVE SUPPLY COMPANY

Article I.—Name

The name of this organization shall be The .... Cooperative Supply Company.

Article II.—Object

Its object shall be to buy and sell on the cooperative plan, articles of common use, including farm products, food supplies, fertilizers, farm machinery, repairs, and articles of domestic and personal use, or in owning or leasing real estate or any other property necessary for conducting its business or to engage in any other activities which are allowable under the cooperative laws of West Virginia whether herein specifically set forth or not.

Article III.—Stockholders

Section 1. Only persons engaged in the production of the agricultural products shall be admitted as members or be issued common stock.

Section 2. Each holder of common stock shall be a member and shall be entitled to one vote. Voting by proxy shall be prohibited.

Article IV.—Meeting of Stockholders

The annual meeting of stock holders of the company shall be held on the.......................... of .... each year at its principal place of business at ...., West Virginia, or at such other place within the said county as the Board of Directors may designate.

Special meetings of stockholders of the company may be held at such times and places as the President, or a majority of the Board of Directors, may order and if 10 percent of the stockholders file a written petition with the Board of Directors asking for a special meeting of stockholders, the same shall be arranged for by the Board of Directors and held according to the provisions for the same made in their order. One-fifth of the stockholders of the corporation entitled to vote shall constitute a quorum for the transaction of business.

Notice of all meetings of stockholders shall be given to each stockholder of record on the books of the Company by mailing a copy of such notice to his or her address as the same appears on the books of the Company at least ten days prior to such meeting; and by publication of such notice at least ten days prior to the meeting in a newspaper of general circulation in ______________ County, West Virginia.

Article V.—Directors

Section 1. The affairs of the Company shall be conducted by the Board of Directors.

Section 2. The election of Directors shall take place at the annual meeting of stockholders, or if for any cause such annual meeting is not held, then a special meeting may be called for that purpose. Such election shall be by ballot, and it shall require a majority of the stockholders voting to elect. No person who is engaged in a business in competition with any business activity of the Company shall be eligible to serve as a director or employee.

Section 3. The number of directors shall be nine, divided into three classes of three Directors each, and the term of office shall be three years, or until their successors have been duly elected and qualified. Of the directors elected at the first stockholders meeting, one-third shall serve until the first annual meeting thereafter, one-third until the second annual meeting thereafter, one-third until the third annual meeting thereafter, or until their successors have been duly elected and qualified, and after the first election one-third of the Board of Directors shall be elected at each annual meeting of stockholders for a term of three years, or until their successors have been duly elected and qualified. A majority of the Board shall constitute a quorum to do business.

Section 4. The Board of Directors shall meet immediately after the annual meeting of the stockholders. Special meetings of the Board shall be held upon the call of the president or upon the written request of five members of the Board.

Section 5. The Executive Committee shall employ an auditor to audit the books of the company and make a complete report thereof to the stockholders at each annual meeting. The Board of Directors or stockholders may employ an auditor when in their judgment it may seem advisable to audit the books of the company and make a report thereof at any regular or special meeting.

Section 6. The Board of Directors shall require every person having the custody of money or anything of value to exceed $100 on account of the corporation, to be bonded in such sum and upon such terms and conditions as shall be approved by the Board of Directors, and a failure to do so shall render the Directors personally liable to the Company for any loss resulting from such neglect.

Section 7. The Board of Directors shall at their first meeting after the annual stockholders meeting select an executive committee composed of the President and two other directors with power to transact all business of the Company when the Board of Directors is not in session, subject to the approval of the Board of Directors. The Executive Committee shall meet on the last Saturday of each month at the office of the Company, and special meetings may be called by the president. The Executive Committee shall have power to employ and discharge all employees necessary to conduct the business of the Company and to fix the compensation of each.

Section 8. The Board of Directors for sufficient reason may remove from office any member of the Executive Committee, by a two-thirds vote of all Directors. But must first give such member ten days notice and a chance to be heard. The stockholders may remove a director in like manner.

Article VI.—Officers

Section 1. The officers of the Company shall be a president and vice-president elected from the Board of Directors and a secretary-treasurer elected from the members. Such officers shall be elected by the Board of Directors for a term of one year or until their successors are elected and qualified, except that the first set of officers shall serve until the first meeting of the Board of Directors after the first annual meeting of stockholders.

Article VII.—Management

Section 1. No speculative dealings shall be engaged in or credit extended to anyone by any employee of the Company except as specifically authorized by the Executive Committee or Board of Directors.

Article VIII.—Capital, Stock, Dividends, and Surplus

Section 1 The capital stock of the Company shall be set forth in the charter of the Company.

Section 2. Only persons engaged in the production of agricultural products shall be admitted as members or shall be issued common stock. Each member shall own at least one share of common stock.

Section 3. Each customer of the Company who does not own any common stock may automatically become a member and stockholder of the Company and the equivalent of what would be due him as a patronage dividend shall be placed to his credit in a special reserve fund until it has accumulated to an amount sufficient to pay for one share of common stock. The Company shall not issue stock to a member until the stock has been fully paid for.

Section 4. The transfer of common stock to persons not engaged in the production of agricultural products is prohibited and such restrictions must be printed upon every certificate of stock subject thereto.

The Company may at any time, except when the debts of the association exceed 50 percent of the assets thereof, buy in or purchase its common stock from the members at the book value thereof, as conclusively determined by the Board of Directors and pay for it in cash within one year thereafter, less any indebtedness due the association by the sellers of the stock.

Subject to the restrictions aforesaid the Company shall buy in or purchase the common stock of deceased members, of members quitting agricultural production, and of members moving out of the trade territory.

Section 5. The sale of preferred stock of a par value of $100 may be authorized at any annual or special stockholders meeting in conformity with the charter of the Company. The preferred stock shall be non-voting and the Board of Directors may provide a sinking fund and fix a date for retirement of the preferred stock.

Upon the dissolution of the Company any preferred stock outstanding shall have first claim as to membership liabilities.

Article IX.—Duties of Officers

Section 1. The president shall be the presiding officer at all meetings of the Board of Directors, executive committee, and stockholders. He shall be ex-officio a member of all committees. He shall sign, execute, and deliver all deeds of conveyance of real estate which the directors may order executed, and shall sign all certificates of stock of the corporation, and perform such other duties as the Board of Directors may direct. In case of absence, inability to act, or death of the president, the vice-president shall discharge the duties of the president until his return, his disability is removed, or the vacancy filled. In the absence or disability of both president and vice-president a presiding officer may be chosen at the meeting.

Section 2. The secretary-treasurer shall attend all meetings of the stockholders, the Board of Directors, and executive committee and keep in a suitable book the minutes of said meetings. He shall have charge of the records and papers of the corporation, shall have charge of and affix the corporate seal to all such documents as may require such attestation; shall issue notices of all meetings; shall countersign all certificates of stock. He shall receive all money paid to the corporation and give his receipt therefor; he shall pay out the same under the direction of the executive committee, and shall make such disposition of the funds on hand as the Board of Directors shall determine. He shall keep in a suitable book a true account of all transactions. He shall make a full detailed report of all receipts and disbursements to the executive committee and the Board of Directors at their regular meetings, and an annual report of the same to the stockholders at the annual meeting thereof and perform all the duties generally incident to his office as secretary-treasurer. His records shall be open to the inspection of any of the directors or stockholders during the business hours.

Article X.—Refunds and Surplus

Section 1. The Board of Directors before declaring any refunds or making any appropriations hereinafter mentioned, shall classify the business done to date, according to the company's net profits on each commodity or line handled so as to enable the Company to distribute the surplus refund in a just and equitable manner to the members.

Section 2. The Board of Directors of the Company is authorized, from the surplus, net profits, of the business, in harmony with the provisions of the charter and of these by-laws, to declare dividends and refunds and appropriate the net profits as follows:

First, A dividend on the preferred stock shall not exceed 8 percent for any one year, which said dividend on the preferred stock shall be cumulative.

Second, After payment of current and accumulated dividends on preferred stock, a surplus and reserve fund (to cover depreciation and possible losses and provide for facilities required in the business and the retirement of indebtedness incurred) shall be created from the net earnings of the Company by setting aside before any patronage refund is declared, not less than 5 percent nor to exceed 20 percent of the surplus net profits in any one year, according to the discretion of the Board of Directors, until such surplus and reserve fund is equal to the total amount of the paid in capital stock.

Third, After the payments of dividends and appropriation to surplus reserve funds, as aforesaid, if any surplus net profits are left the same shall be distributed as a patronage refund, to the holders of the common stock of this company, in proportion to the volume of business done by said member with the Company in each of the classifications as determined by the Board of Directors herein before provided for.

In ascertaining and determining such refund the Board of Directors shall take cognizance only of purchases by the members for their own individual use and of the sales of their own personal farm products sold by the Company.

Article XI.—Vacancies in Board

Any vacancy occurring in the Board of Directors by reason of death or otherwise, shall be filled by the Board of Directors until the next annual meeting.

Article XII.—Fiscal Year

The Fiscal year of the Company shall begin as of ________________________________ and end as of ________________________________.

Article XIII.—Compensation

The members of the Executive Committee may receive a compensation of ______________ dollars per day for each regular and special meeting attended and in addition, ______________ cents per mile for each mile traveled to and from each meeting.

Article XIV.—Amendments

These by-laws may be repealed or amended by a two-thirds vote of the stockholders present at any regular meeting, or by a two-thirds vote of the stockholders present at a special meeting held for that purpose. To change property rights and interests a three-fourths affirmative vote of all members is necessary.

Financing and Membership

The need for the committee on financing and membership will be determined by the decision to organize a warehouse. A car-door business requires working capital only and this but for a day or two when the car is being unloaded. This capital can very conveniently be supplied by the car-door purchasing agent or borrowed from a bank. For a warehouse, however, fixed capital as well as working capital must be provided, since a stock of goods must be kept, and equipment and very often real estate must be purchased.

The methods employed in raising this necessary capital is of vital importance from the standpoint of (1) sufficient capital, (2) the security of the money invested, (3) the control of the company. Several methods for raising capital have been used by the farmers' warehouses in the state. These methods may be listed as follows:

1. Collateral notes given by the members.
2. Loans from individual banks and county farm bureaus.
3. Contributions from the members.

4. Using accumulated farm bureau dues.
5. Using accumulated profits of the business.
6. Sale of stock, both common and preferred.

The sale of capital stock has been found to be the best practice whenever rather large amounts of fixed capital have been required. More than half of the farmers' warehouses in the state have sold stock in raising the fixed capital requirements. To supply real estate alone from $1500 to $24,000 of fixed capital have had to be raised. Furthermore, the Cooperative Act makes special provisions for capital stock which may be either preferred or common.

The law provides a number of restrictions, the most important of which are that no stockholder shall own more than one-twentieth of the common stock, and only operating farmers may be stockholders, members, and patrons. The above restrictions are not placed on the ownership of preferred stock. Convenient alternatives are thus allowed in the sale of capital stock.

Good business practice demands that enough capital stock should be sold to provide all the fixed capital required for equipment and real estate and furthermore, to provide working capital for a minimum stock of supplies. The other methods which have been listed herein should be used as temporary expedients or mere supplements to the capital raised by the sale of stock. For peak business periods additional capital may be borrowed to advantage. The success of the company depends in large part in anticipating the capital requirements and actually raising the money at the start. In order to do this the probable growth of the business must be estimated.

Once it has been decided to raise capital through the sale of stock, a committee should work out the details carefully with regard to:

1. The kind of stock.
2. The par value of the stock.
3. The number of shares to be authorized.
4. The relation of stock ownership to voting.
5. The retirement, repurchase, and assignment of stock.
6. The methods of selling the stock.

In making the foregoing suggested plans for the sale of stock, the following cooperative principles and practices should be strictly adhered to:

1. The purpose of the company is savings and service for the patrons and not profits on capital stock. The dividends on the stock shall, therefore be limited to a nominal rate, for example 6 or 8 percent.

2. The voting power shall be kept democratic; each member having but one vote regardless of the amount of stock owned.

3. Each patron shall become a member as required by the Cooperative Act and shall have some share in promoting the enterprise.

4. Each patron and member shall participate in the profits of the company through the payment of patronage dividends.*

Since each patron must be a member according to the State Cooperative Act, various devices have been suggested to comply with this provision, and also to give each member some of the responsibilities and burdens as well as the benefits of cooperation. Two plans will be suggested.

* Patronage dividends is a term used to designate the dividends paid out by cooperative companies to its members on the basis of the amount of business done with the company rather than on the basis of the amount of stock owned.

1. Some warehouse companies in the state require, as a qualification for membership, that each patron be a member in good standing of the County Farm Bureau. To make this requirement effective, these companies reserve the right to apply the patronage dividends to the payment of the annual farm bureau dues. When this plan is used the requisite capital may be raised by the sale of preferred stock in unlimited amounts to members and non-members. This stock should preferably carry no voting power and should have a fixed cumulative rate of dividends which is sufficient to induce investors to take the risks involved.

2. The other plan may be stated as follows: Stock ownership is made a qualification for membership and patronage. As a first step, common stock is sold to all prospective farmer patrons who are willing to take at least one share of stock at the time the company is being organized. Secondly, some shares of this stock will be held for sale to any patrons who may later decide to buy. Finally, in order to permit the patronage of farmers who are not willing or unable to purchase stock, a device must be worked out to make each the owner of at least one share. This is accomplished by applying the annual patronage dividend of each non-stock-holding patron as an installment on the purchase price of one share of common stock. This stock is held by the company until it shall be paid for in full. In this manner each patron becomes a stockholder and member, and more capital is raised as the business grows. There are many advantages in the use of this plan in place of the first one suggested. This plan is incorporated in the model by-laws given herein.

Since no persons but those engaged in agricultural production are permitted to be patrons and voting members, some provisions should be made for the retirement and repurchase of the stock. The by-laws should provide for the methods of carrying out these provisions in the cases of deceased members, members leaving agricultural production, and members moving out of the trade territory. The assignment of common stock should be prohibited insofar as the

TABLE 8.—Number of Stockholders and Par Values of Common and Preferred Stock of 14 West Virginia Warehouses.

Warehouse Number in the Order of the Date of Beginning Business	Common Stock		Preferred Stock	
	Number of Stockholders	Par Value of Stock	Number of Stockholders	Par Value of Stock
1	33	none	none	none
2	(Contributors) 49	no data	none	no data
4	(Shareholders) 226	Non-par	none	none
5	25	$50.00	none	none
6	85	$10.00	none	none
7	100	$25.00	none	none
8	72	$ 1.00	90	$ 10.00
9	233	$ 1.00	77	$100.00
10	80	$25.00	none	none
11	15	$25.00	none	none
12	none	none	none	none
13	none	none	none	none
14	225	$ 1.00	37	$ 1.00

TABLE 9.—Total Amounts of Authorized Capital Stock and Paid-up Capital Stock for 14 West Virginia Warehouses.

Warehouse Number in the Order of the Date of Beginning Business	Total Authorized Capital (Both Common and Preferred Stock)	Total Amount of Stock and Shares Paid Up
1	Unincorporated	$ 1,015.90*
2	Unincorporated	3,000.00 (in shares)
3	No data	No data
4	No par value	3,146.00
5	$10,000.00	2,000.00
6	10,000.00	5,800.00
7	50,000.00	32,962.82
8	25,000.00	9,380.00
9	10,000.00	8,250.00
10	25,000.00	2,800.00
11	15,000.00	2,200.00†
12	No stock yet authorized	None
13	Unincorporated	None
14	Incomplete data	3,500.00
Average Amount for Those Reporting	$20,714.28	$ 6,733.16

*The members loaned various sums which are being paid back in ten annual installments consisting of 14 percent of the sum contributed.
†Approximately.

law will permit, and the company should be ready to repurchase under appropriate restrictions any such stock offered for sale.

In planning the sale of stock the entire community or territory should be laid off into districts. Men or committees may then be appointed to canvass the farmers in each district. The solicitors should be favorably known in the communities. Records shall be kept of the men who refuse to buy stock and their reasons for doing so. These men may be called upon a second time by another man or committee. In no case should the solicitors be paid for the sale of stock. If this must be done, it is questionable if the farmers are yet ready to conduct a cooperative enterprise.

Table 8 shows the number of stockholders and the par value of the stock of several warehouses in operation in West Virginia. It will be noted that the number of stockholders vary from 15 to 233 and the par value of stock from $1 to $100. There has been a tendency to make the par value of a share of stock too small. Experiences of most cooperative companies indicate that $50 should be the minimum for common stock and $100 for preferred stock. Doubling these amounts has many advantages.

Table 9 shows that there are variations in the authorized capital stock of from $10,000 to $50,000 and an average of $20,714.28 for the seven warehouses reporting. The paid-up stock ranges from $2,000 to $32,962.82 with an average of $6,733.16 for those reporting. It will be noted that the average paid in stock is approximately one-third of the authorized capital. Most companies have found themselves without sufficient funds, therefore, every endeavor should be made to anticipate future requirements before business is begun. It is usually much easier to sell stock during the promotion period than later.

TABLE 10.—Estimated Total Amount of Capital Consisting of Working Capital and Value of Real Estate Used in the Business During the Last Fiscal Year or Part of Year, Compared to Value of Products Sold for Same Year for 9 West Virginia Warehouses.

Warehouse Number in the Order of the Date of Beginning Business	Estimated Amounts of Working Capital Plus Real Estate Values	Estimated Average Amounts of Working Capital	Value of Real Estate Which Was Being Used for Warehouses	Value of Products Sold During Year
3	$69,000	$45,000	$24,000	$112,000
7	57,000	36,000	22,000	77,084
9	21,410	16,000	5,410	101,952
1	13,700	11,500	2,200	26,000
8	12,750	8,000	4,750	40,937
6	10,500	6,000	4,500	52,579
4	9,500	8,000	1,500	41,500
10	9,500	4,000	no data	35,000 (7 months)
12	8,400	5,100	3,400	18,000 (6 months)

Table 10 shows the estimated amounts of capital used by fourteen warehouses in West Virgiria. The variations in the total capital employed range from

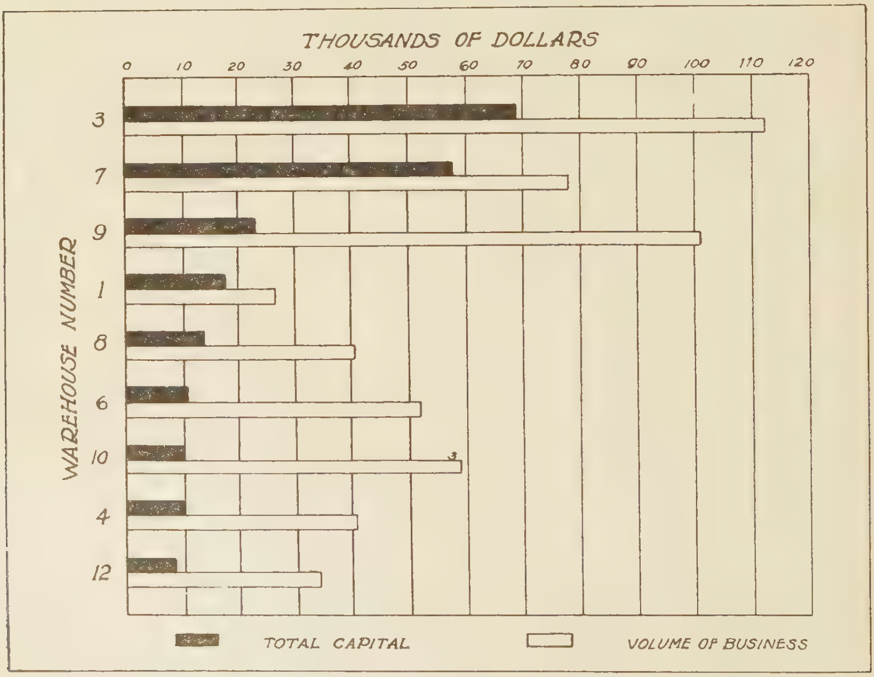


Fig. 2.—Comparison of total capital and volume of business for nine West Virginia Warehouses for the fiscal year ending June 30, 1925.[1] See Table 10 for data on which this graph is based.

[1] Total capital as here used is the sum of the working capital and real estate values.
[3] Estimated from seven months business.
[4] Estimated from six months business. (Refers to warehouse No. 12.)

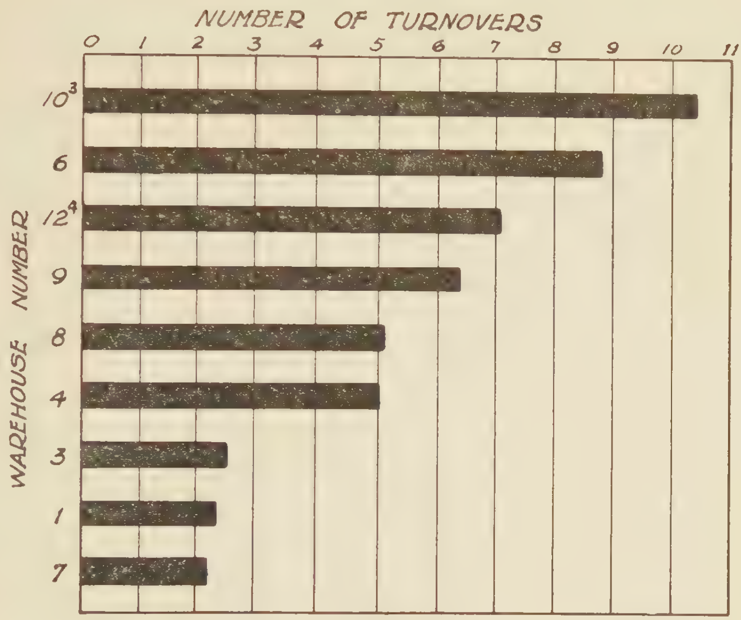


Fig. 3.—Comparison of turnovers of working capital for the nine West Virginia warehouses compared in Figure 2, for the same period of time or the fiscal year ending June 30, 1925 [1]

$8,400 to $69,000. The differences in the amounts of both working capital and real estate values show similar wide variations. The relationship of the value of the real estate to the working capital ranged from about one-fifth to considerably more than one-half. This relationship is of great importance to the success of the business.

Figure 2 shows graphically the relationship between the total capital and the volume of business for each of nine warehouses for the fiscal year ending June 30, 1925. There is a wide range in the number of turnovers per year, a range of about 1 1/3 to 6 1/3 turnovers. The number of turnovers is a good indication of efficiency in the use of capital and usually of the efficiency of the business as a whole.

Figure 3 gives graphically the number of turnovers of the working capital. There is a variation of from about 2 1/5 to 10 1/3 times annually. These turnovers are good indicators of the influence of the credit policies, the stocks of goods carried and the volumes of business on the operating efficiency of each warehouse.

2 Working capital consists of all capital owned and borrowed except real estate.

3 Estimated from seven months business.

4 Estimated from six months business.

Site and Business Facilities

The committee on site and business facilities has three alternatives, namely: (1) to rent a building, (2) to purchase an existing building, or (3) to build a new one. In making a choice the committee should very carefully consider the adaptability of the various sites available. Very often farmers fail to realize the importance of being located: (1) on a railroad spur which saves a great deal of handling of heavy supplies; (2) in the village or city which is commonly patronized by most of the prospective patrons; (3) near the place where most of the members go when in town attending to other business. Inconvenient locations have been one of the chief difficulties of a number of farmers' warehouses in the state. Expensive retail sites need not be selected, but the warehouse should not be a great distance from the retail district. In large cities expensive real estate makes the selection of a site very difficult and in many cases the selection of a site outside of the main business district, or the location in a smaller town, will be necessary.

When deciding to rent, buy, or build, some of the factors to be considered are:

1. The amount of capital available in addition to that needed for working capital.

2. The relative annual costs of each of the three alternatives in obtaining a building.

3. The possibility of buying out a competitor.

4. The time when it is most desirable to begin the business.

5. The risk involved in beginning the business may be a sufficient reason for renting a warehouse, since the business can be more quickly closed up and the assets more easily returned to those contributing them.

TABLE 11.—Real Estate Costs and Values for West Virginia Cooperative Warehouses Considered in This Study.

Warehouse Number in the Order of the Date of Beginning Business	Original Cost of the Real Estate	Estimated Value of Warehouse Real Estate at Time of Survey
1	$ 2,200	$ 2,000
2	3,000	3,000
3	24,000	27,500
4	1,500 (land leased)	1,500
5	1,800	2,000
6	4,500	6,000
7	21,000	26,000
8	4,750	4,750
9	5,410	5,410
10	$30 per month rent	no data
11	2,200	2,200
12	3,400	4,100
13	$130 per year rent	no data
14	$50 per month rent	no data
Average for Owned Warehouses	$6,705.45	$7,678.18

6. The adaptability of buildings and sites available for purchase and rent.

7. The business sagacity of the committtee and the favorable opportunities open at the time of organization.

Table 11 gives the original cost of the real estate of eleven farmers' warehouses in West Virginia. It will be noted that in several cases there has been a rise in the values, due in part to repairs and additions, but in a large part due to the tendency in recent years for urban real estate to advance in price.

The purpose of the warehouse business is primarily to reduce the cost of obtaining supplies and not to make a profit on advancing real estate values. These advancing values are often so highly capitalized as to prohibit the business from earning sufficiently to pay the interest charges on the price paid for the land.

Whether the decision is to build or to buy, a reliable, disinterested, experienced person should be procured to examine and appraise the property or to give reliable estimates as to the costs of building a warehouse, and to examine all plans and bids submitted by contractors.

A humble beginning is often desirable for it is quite easy to obtain larger business facilities when the volume of business warrants such expenditures. A large, expensive warehouse is often too great a burden for a struggling cooperative business which must build its business by the slow process of justifying itself through high quality products offered at retailing margins which are low enough to obtain and hold a sufficient volume of business.

BUSINESS PLAN

The business plan should be carefully worked out by the executive committee in consultation with the manager. Too often the manager is given full authority in this matter, but sharing the responsibility with the executive committee will give the manager more confidence, and a more secure position in carrying out the policies agreed upon. The manager should always be in a position to appeal to higher authority if it becomes absolutely necessary in dealing with the patrons. The following suggestions are given as a workable plan for a business operation.

Business Policy of Car-Door Associations

A car-door business is founded upon orders in advance and cash payments when the car is unloaded. This is the minimum of service which can be rendered, and any deviation from this plan will invariably increase the costs of handling. Table 12 shows the charges on the most common products handled by car-door associations. The most common handling charges amount to from 2 to 5 percent of the cost price. These charges are surprisingly low. They are from one-fifth to one-third of the usual warehouse charges.

Most associations pay the car-door agent on the tonage basis. A few associations pay a commission based upon a certain percentage of the cost price. Both plans seem to work out satisfactorily for all parties concerned. The margins allowed the car-door agent should be sufficient to pay interest on capital advanced, to compensate for risk taken, to encourage and compensate for the use of a due amount of diligence in collecting orders at stated intervals, in keeping adequate accounts, and extending reasonable services in unloading the car.

TABLE 12.—Handling Charges for Seven West Virginia Car-Door Associations Included in This Study.

Car-Door Association Number in the Order of the Date of Beginning Business	Handling Charges in Percentages of the Cost Prices			
	Feed	Flour	Fertilizer	Lime
1	3 to 4	3 to 4	2 to 5	3
2	3 to 4	3 to 4	2 to 5	3
3	2	2	2	2
4	1 to 5	1 to 5	2 to 5	1 to 5
5	4	4	4	4
6	3 to 4	3 to 4	4	4
7	3 to 4	1	no data	20 to 30

The following is a list of the products handled by five county farm bureau car-door associations in the order of total value of the amounts purchased for the fiscal year: (1) Feed and flour, (2) fertilizers, (3) lime, (4) seed, (5) salt, (6) sugar, and (7) farm machinery.

Business Policy of Warehouses

The board of directors and executive committee declare the general business policy of the company. This should be done after consultation with the manager and after due consideration of the factors involved. Specifically the board should determine:

1. Commodities to be handled.
2. Policy to be followed with regard to prices and retailing margins.
3. What types of credit accounts, if any, to permit.
4. Buying policy to be followed.
5. Services to be rendered other than selling supplies.

COMMODITIES HANDLED

The commodities which a particular warehouse should handle will depend largely upon the need for such supplies by the patrons, the volume of such supplies required, and the facilities for handling such products at reasonable margins.

The following is a list of the products handled by eleven county farm bureau warehouses in the order of the total value sold during the fiscal year: (1) Feed and flour, (2) fertilizers, (3) seed, (4) farm machinery, and hardware, (5) lime and limestone, (6) hay, (7) sugar, (8) cement, (9) spray material, (10) miscellaneous—(a) canned foods, (b) coffee, (c) oyster shells.

PRICE POLICY

All the warehouse managers consulted were convinced that the prices charged should be the same to all patrons. This has been found necessary in order to avoid complexities in carrying on the business and to avoid misunderstanding and conflict. Moreover, experiences of warehouse and cooperative store managers elsewhere have shown the wisdom of avoiding "cut-throat" prices or the plan of keeping the retailing margins so low as to barely pay the cost of doing business. It is a safe business practice to ask a fair competitive price for supplies and to rebate any profits above the costs of doing business to the patrons at the end of the fiscal year. This practice gives stability and safety to the business and tends to avoid any undue enmity and unfair tactics on the part of competitors. In the end, it results in furnishing the patrons with supplies at the actual cost of doing business. This price policy can be further commended in that it gives a tangible and clearcut advantage in the form of patronage

dividends to the members in dealing with their own company. Moreover, non-members cannot obtain the same benefits by remaining outside and continuing to purchase from the competitors.* They will, therefore, be encouraged to become members.

Table 13 gives the average retail margins for small lots at the various warehouses in the state for the last fiscal year. The average retailing margins ranged for the various kind of supplies from 9.5 percent of the cost price for seed to 20.1 percent for lime. The greatest part of the business was done in feed and flour and the margins on these products ranged from 6 to 20 percent and averaged 12.6 percent. The wide range in retailing margins by the various warehouses was largely due to the wide range in the volume of business, the kind of services extended, the nature of the competition and the price policy followed. The lower retailing margins were due in most cases to the sale of larger volumes of supplies which were called for at the warehouses and sold almost wholly on a cash basis.

The retailing margins which are necessary for any warehouse, are directly affected by the kind of service demanded. This service ranges from advanced orders with cash at the car-door to a continuous supply of a great variety of supplies delivered at the farmer's door on a credit basis.†

The most common types of service extended by the various county farm bureau business units may be listed as follows:

1. Ordered in advance and paid for at the car-door.

2. Ordered in advance, stored temporarily, and paid for when obtained.

3. Limited stock of staple supplies at the warehouse and cash demanded at the time of purchase.

TABLE 13.—Average Retailing Margins for Small Lots at the Warehouses Included in This Study for the Fiscal Year Ending June 30, 1925.

Warehouse Number in the Order of the Date of Beginnine Business	Average Retailing Margins in Percentages of the Cost Prices					
	Feed and Flour	Fertilizer	Salt	Seed	Lime	Miscellaneous Supplies
1	10	5½	20	8	17	13
2	8	8	No data	8	No data	8
3	15	4½	20	15	9	15
4	13	12	20	4	10	10
5	11	11	11	11	No data	11
6	20	16	12	15	25	15
7	10	17½	No data	No data	No data	No data
8	13	13	No data	No data	No data	8
9	10	20	10	10	50	15
10	10	10	10	5	10	10
11	No data	10	No data	No data	No data	No data
12	20	15	No data	10	20	10
13	12	10	No data	No data	No data	No data
14	10	No data	No data	No data	No data	No data
15	6	No data	No data	No data	No data	No data
Average for Those Reporting	12.6	11.7	14.2	9.5	20.1	11.5

* It has been found that most private feed dealers will not unduly lower the retailing margins in competing with a cooperative company, but will tend to keep prices about on the same general level.

† Most warehouses will order in carload lots at lower handling charges than for smaller lots, often as low as 2 to 5 percent of the cost price.

4. Limited stock of staple supplies at the warehouse and credit allowed for small amounts for short periods of time.

5. A full stock of staple supplies at the warehouse and liberal extension of credit allowed.

6. A full stock of staple and seasoned supplies at the warehouse, liberal extensions of credit allowed, and delivery made to the farms by truck.

Local conditions, custom, and competition, together with the available business capital and facilities will to a large degree determine how far the services should be carried. That additional services must be paid for must be kept constantly in mind. Warehouse services have been approximately three times as high as car-door services as practiced by the various farm bureau service units in the state. These additional services and charges are often desirable and the demands and customs of the members should be known before the business is organized.

Due to competition it is difficult to keep the margins charged uniform for different periods of time and for various kinds of supplies. Care should be exercised, however, to prevent an undue burden on some supplies and too light a burden upon others. There should be a constant effort to maintain a direct relationship between costs of handling and the retailing margins charged.

Most of the warehouses handled supplies through orders in car-lots at rates comparable to those charged by car-door associations, ranging from 1 to 5 percent.

CREDIT POLICY

To avoid the serious dangers of credit extensions, warehouses must demonstrate to the patrons that buying for cash really pays not only interest on the money but considerably more. The patrons must clearly understand that a credit business requires more capital, more costly management, and larger retailing margins. The larger margins are needed for the most part to take care of the risks and to pay for some accounts which inevitably cannot be collected. The patrons who buy for cash are constantly paying part of the expense of carrying the credit accounts of other patrons.

Moreover, selling supplies for cash or at most on thirty day accounts, gives a competitive advantage which private dealers overcome with difficulty. It can be readily understood that supplies sold on much narrower retailing margins soon induce many farmers to take advantage of these lower prices whenever they find it possible to pay cash. The prosperous and more reliable farmers will be the first to derive the benefits of buying for cash. This opportunity to buy at lower prices for cash tends to compel private competitors to lower their margins during the time when their best customers are being drawn away and only the patrons of poor and uncertain financial standing are left. Quoting a private feed store owner in competition with a cooperative warehouse: "I must go either on a cash basis or out of business." With the farmers' cooperative warehouses selling at lower margins on a cash basis, an alternative is at hand which is effective whenever supplies are being sold by private dealers on the credit basis at exhorbitant margins.

The disadvantages of a cooperative company's doing a credit business may be pointed out as follows:

1. Inadequate funds for credit extensions.

2. Higher costs entailed by credit service.

3. Necessary partiality shown by the manager.

4. Difficult collections from the members who have, of course, a voice in the management of the company.

5. More experienced and higher salaried managers are required.

6. Impaired credit standing among wholesalers and often inability to take advantage of cash discounts.

7. Opportunity of influential members to obtain disproportionate amounts of supplies on credit.

8. Inability to regulate retailing margins in the trade territory because of high costs.

9. Lack of opportunity for members to take advantage of the lower costs in buying for cash.

The advantages which accrue in doing business on a cash basis are very similar to the competitive advantages enjoyed by cash and carry grocery stores. There is a place for a cash supply business in every trade territory of normal size. Farmers' cooperative warehouses are particularly adapted to carrying on this type of business. A substantial part in some instances, or even a rather small fraction of the business of a trade territory in others is sufficient to regulate retailing margins.

Table 14 shows the total amount of credit outstanding to patrons by each warehouse, and the maximum amount extended to individual patrons at the time of the survey. For the warehouses reporting credit extensions, $800 was the smallest total amount and $19,222.82 the largest. The amount outstanding to single individuals is for several warehouses seriously out of proportion to the amount of business done and working capital available. This practice of permitting a single individual to obtain several hundred dollars worth of supplies on credit is poor business practice and is unfair to other members of the association.

TABLE 14.—Estimated Total Amount of Credit to Patrons and the Maximum Amount of Credit to One Patron on Certain Dates, Compared to Amounts of Working Capital Used During the Fiscal Year for 12 of the Warehouses Included in This Study.

Warehouse Number in Order of the Date of Beginning Business	Estimated Total Amount of Credit to Patrons	Maximum Amount of Credit Extended to One Patron	Estimated Amounts of Working Capital Used Last Fiscal Year
1	$ 6,000.00	$638.46	$11,500.00
2	No credit	No credit	No data
3	17,819.00	800.00	45,000.00
4	3,700.00	499.00	8,000.00
5	2,900.00	325.00	No data
6	800.00	Very small	6,000.00
7	19,222.82	No data	36,000.00
8	3,827.85	200.00	8,000.00
9	7,844.50	800.00	16,000.00
10	2,000.00	125.00	4,000.00
11	No data	No data	No data
12	1,500.00	No data	5,100.00
Average for Those Reporting	$ 6,561.32	$483.92	$15,511.00

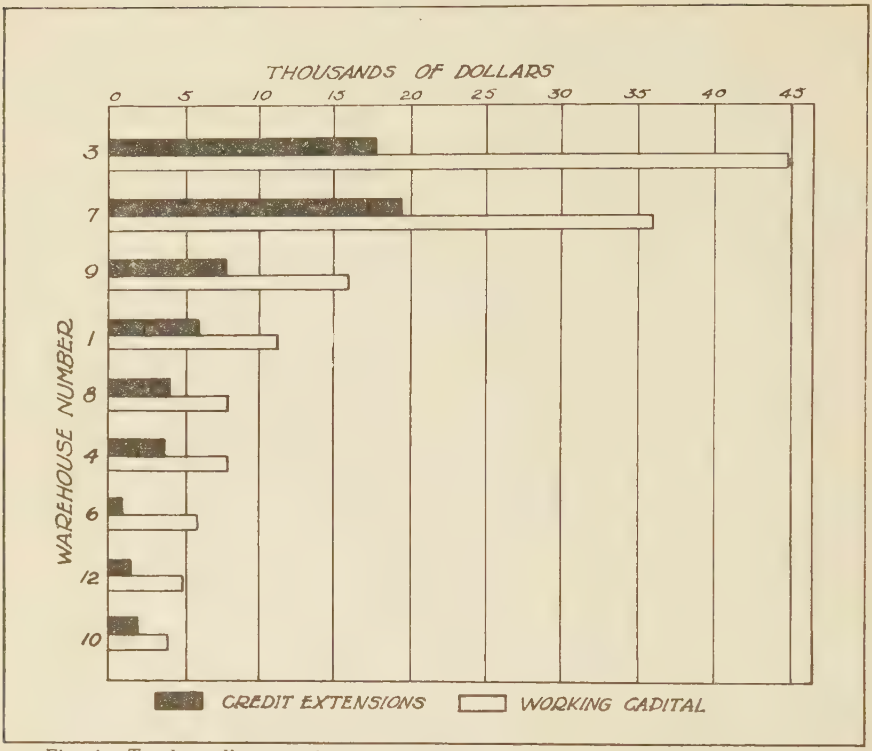


Fig. 4.—Total credit extensions to patrons on certain dates compared to average annual amounts of working capital for nine of the warehouses included in this study. See Table 14 for data on which this graph is based.

Figure 4 compares the amounts of credit extensions on certain dates to average amounts of working capital for the previous fiscal year. Credit extensions equal approximately one-half of the working capital for seven of the nine warehouses. This, however, does not indicate that all the warehouses have about the same credit policy. A few warehouses have a large percentage of their credit accounts outstanding for from four to ten months and even more than a year. Other warehouses have a rapid turnover of credit accounts by working on a 30 day basis. It can be readily understood how the length of the credit accounts determine the efficiency with which this portion of the working capital is used. Long credit accounts have proved a serious handicap in that they have:

1. Diminished the available working capital.
2. Made rapid turnovers of capital impossible.
3. Forced reductions in the stocks of supplies.
4. Impaired the confidence of the members and stockholders.
5. Made extensions of short time credit very difficult if not impossible.

Credit extensions are a constant source of worry to the directors and managers and add greatly to the complexity of the business. The problem of keeping credit extensions within bounds has been the most perplexing difficulty confronting the several warehouse managers. Several methods have been tried

to overcome the tendency to force the company to carry too large a burden of credit accounts. These include:

1. The manager is held personally liable for all credit extensions.
2. Interest is charged on all accounts after 30 days.
3. Interest bearing notes have been required on all accounts after 30 days.
4. Credit accounts have been made a special privilege extended only as a special favor under particular circumstances.
5. Professional collecting agencies have been employed to collect accounts in arrears.

Figure 5 illustrates graphically the wide differences in the credit business of nine warehouses. It will be noted that the credits outstanding on certain dates during the survey ranged from 1.52 to 24.94 percent of the volume of business for the last fiscal year. The length of the credit accounts as well as the rapidity of the stock turnover are far more important in influencing the above percentages than is the proportion of the working capital outstanding on credit accounts. It is perhaps needless to point out that the warehouses with the

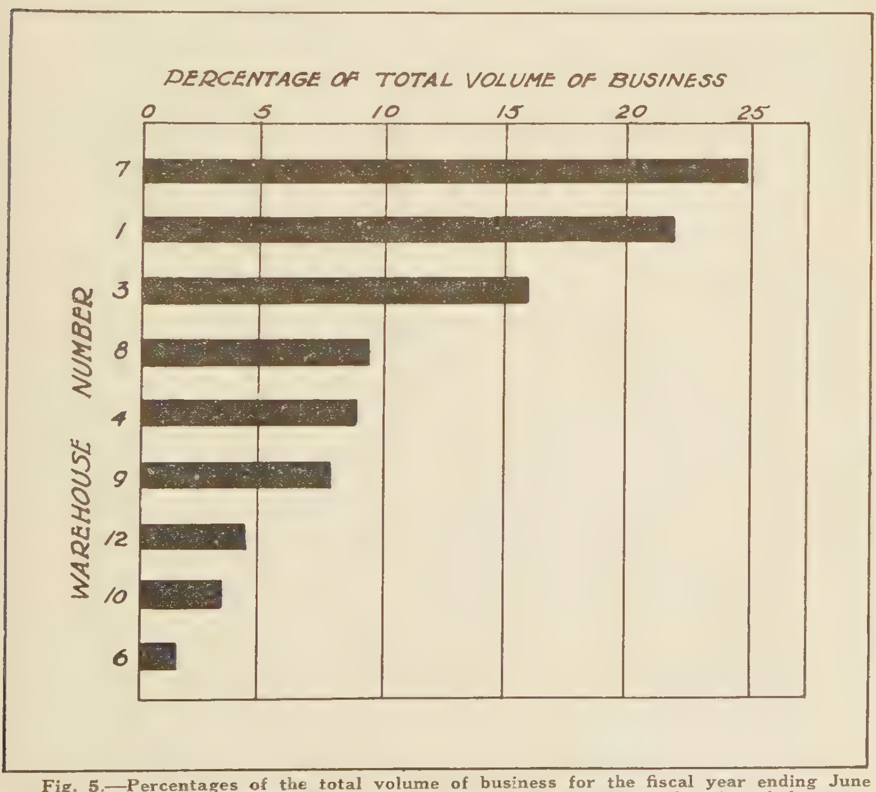


Fig. 5.—Percentages of the total volume of business for the fiscal year ending June 30, 1925, represented by outstanding credit accounts on certain dates for nine of the warehouses included in this study. Compare with Figure 4. See Tables 10 and 14 for data on which this graph is based.

three lowest percentages of credit accounts are in sound financial circumstances, while those operating on more than a 10 percent basis are, with one exception, in somewhat of a hazardous position.*

The attitude and ability of the manager is the greatest factor in keeping credit accounts within bounds. He should not, however, be given all the responsibility. The board of directors, and executive committee, should give their sanction to the refusal of credit in large amounts and for long periods of time. In fact, the executive committee should review each of the credit accounts frequently. Under certain circumstances the directors should put the business on a strictly cash basis. Constant progress toward a cash business should be the aim of farmers' cooperative supply companies.

BUYING POLICY

Ordering the stock of commodities will in most cases be left in the hands of the manager. It is possible, however, for the executive committee and officers to lay down general rules to be followed. These rules should not be too restrictive for the manager is usually in a better position to know what is required than are the directors. The following may be taken as workable and wise restrictions:

1. Advance or speculative orders far in excess of current requirements should not be placed without the consent of the executive committee. Serious losses often arise from such transactions.

2. The prices charged should be regulated by local and central market prices rather than by the cost of the supplies on hand. Experience has demonstrated that if the usual retailing margins are charged during rapidly rising prices, an insufficient amount will be obtained to compensate for unavoidable losses incurred when there are rapidly falling prices.

3. New lines of supplies should not be ordered without the consent of the executive committee because of the extra capital requirements and other complications involved.

4. Joint purchases with other retail firms and companies should be very carefully guarded since the cooperative incorporation act prohibits dealing with anyone but members who must be producers of agricultural products. For the same reason a wholesale business with general retail stores should be avoided.

5. A general policy may be carried out with regard to the purchase of certain classes of supplies. They may be classified as follows: staple supplies to be kept in stock at all times, seasonal supplies to be kept in stock for certain periods, and special supplies purchased only when specifically ordered by individual patrons.

The manager needs all his experience and business shrewdness in placing orders for high quality supplies at the lowest prices. He should build up business relationships based upon confidence and should not let temporary price advantages determine his purchases. Confidence in quality, and in consistent and prompt service are often as important as the price. In the foregoing respects a cooperatively controlled brokerage business can be of great service to the local supply warehouses and car-door agencies.†

* This company is doing a rather large wholesale business which is seldom done on a cash basis.

† The West Virginia Farm Bureau Cooperative Association is now engaged in a brokerage business for the several warehouse companies and car-door associations in the state.

SERVICES OTHER THAN SELLING COMMODITIES

Local conditions, the volume of business, and the need for types of services other than selling commodities will largely determine the course followed by the warehouse management. The following list gives various types of services which have been rendered by fourteen county farm bureau warehouses in West Virginia, arranged according to the numbers that have been assigned the warehouses and used throughout this discussion:

1. Retail locally grown seed, hay, and grain.
2. No service other than handling commodities.
3. Market small amounts of potatoes.
4. (a) Sell eggs and poultry on a commission basis.
   (b) Mix feeds for patrons.
5. No service other than handling commodities.
6. Store wool on premises.
7. Use facilities for loading potatoes.
8. (a) Buy cream for cash and ship to creameries.
   (b) Buy poultry, eggs, hides, calves, and potatoes for cash and ship to central markets.
   (c) Use truck for outside hauling.
9. Retail locally grown seed, hay, and grain.
10. (a) Assemble wool for state wool pool.
    (b) Exchange supplies for locally grown potatoes.
11. Assemble wool for wool pool.
12. (a) Buy cream for cash and ship to creameries.
    (b) Act as selling agent for home canned tomatoes.
13. No service other than handling commodities.
14. (a) Buy cream for cash and ship to creameries.
    (b) Furnish scales for cattle shippers.

Additional services are being rendered by the smaller and newer warehouses. It is often feasible where the volume of commodities handled is insufficient to pay over-head expenses to take on other types of business such as those listed for the warehouses included in this study. This is found convenient also where the supply business tends to be rather seasonal. In other cases some new farm enterprises have as yet no marketing agencies and this business is forced upon the management. Where the volume of supplies handled is sufficient to require the full time of the manager, however, other services are not sought, and in fact are unduly burdensome. If the additional services are rendered, additional labor must often be employed for this purpose alone. For the foregoing reasons the more successful supply companies are doing very little else than selling commodities. As a general principal, it is well to keep a cooperative business restricted to a limited number of services and lines of endeavor.

MANAGEMENT

Management problems will be treated in this discussion under the following headings: Board of directors and executive committee, manager, and accounting system.

The Board of Directors and Executive Committee

The members of a cooperative company delegate their authority to a board of directors. The State Cooperative Act is rather definite in regard to this matter; Section 12 begins with this statement: "The affairs of the association shall be managed by a board of not less than five directors, elected by the members or stockholders from their own number." Other provisions of this section may be found on page 49. The authority may be further delegated by the board of directors to an executive committee consisting usually of three members, all of whom are members of the board. This committee may assume "all the functions and powers of the board of directors subject to the general direction and control of this board." This practice permits the unified control and centralized responsibility demanded by good business practice.

The men chosen as members of the board of directors and of the executive committee should be men of integrity, the most experienced in business to be found in the organization, well-liked and respected, and actually interested in the operating success of the warehouse because of rather large and continuous patronage.

The length of term for the directors should be for more than one year, since each new director must learn the business before he can serve most efficiently. This can be accomplished by making the term of each director 3 years and by electing one director each year. This will keep the majority of the old board members over the period of any one election. It is a good business practice to keep the same directors and officers whenever they are giving good service. "Passing around the honors" usually means less efficient management. This applies even more strongly to the manager and secretary who carry on the routine business.

Reasonable compensation should be paid the directors and executive committee. Uuless this is done a lack of interest, poor attendance at meetings, and too few meetings are apt to be the result. This applies especially to the executive committee which should meet at least once a month, and go over the business thoroughly with the manager. With a strong executive committee functioning, it is not necessary to have more than semi-annual or quarterly meetings of the board of directors. Meeting but a few times each year, traveling expenses are often sufficient compensation for the board of directors, but the executive committee should receive a fixed compensation besides traveling expenses for all regular and special meetings.

Too much emphasis cannot be placed upon the direct responsibility of the executive committee in keeping in close touch with the business at all times. The meetings of the executive committee should be scheduled definitely and the business handled with precision and dispatch.

The Manager

The most important function of the executive committee or board of directors is the selection of a manager. It is well to have several eligible men in mind before the company is organized. All personal preferences should be cast

aside, and the best qualified man selected. In general the manager must be well-liked by the members and patrons and at the same time be a man who will promote the business interests of the company. "It requires a man with tact, with ability to appraise human nature, and with the rare faculty of being able to decide impersonally against individual members in controversy without giving offense." He must be a man who has a deep sense of responsibility in making the cooperative venture a success. He should have knowledge of cooperative principles and practices and should be imbued with cooperative ideals. A selfish individualistic man will fail as the manager of a warehouse which is run on the cooperative principle of services to the patrons.

It is often unwise to employ a man as manager who has spent a large part of his life in similar business for himself. He cannot easily accommodate himself to the cooperative point of view. The better managers in West Virginia have come directly from the farm to the warehouse, having had some business experience earlier in life. They have as their main assets: the cooperative spirit, integrity of a high order, business conservatism, understanding and sympathy with the patrons, and a willingness and desire to learn the part of the business with which they are not familiar.

Table 15 shows the salary, months employed, and the age of the managers of eleven county farm bureau warehouses in West Virginia. It will be noted that the tenure has been rather brief thus far. This is inevitable in most cases due to the short period of the existence of the company. The salaries range from $600 to $2,000 per year. The most common salary is from $1,000 to $1,500 per year. For the smaller warehouses these salaries may be sufficient, especially in the beginning. But when a warehouse is doing a $100,000 business annually, a salary of less than $2,000 per year is undoubtedly too low to attract and hold the high type of management required. Good services manifested by courteous treatment, low overhead costs, prompt collections, a workable accounting system, and a growing business should be rewarded by a gradual increase in salary for the manager. He should feel that he is doing as well financially as he could do if employed elsewhere.

TABLE 15.—Salary, Months Employed, and Age of the Managers of Eleven County Farm Bureau Warehouses in West Virginia.

Warehouse Number in the Order of the Date of Beginning Business	Annual Salary of Manager	Months in the Employ of the Company	Age of Managers
1	$1,020	32	50
3	1,800	12	50
4	1,150	24	45
6	1,500	26	28
7	2,000	24	45
8	1,500	26	27
9	1,700	20	38
10	1,200	7	45
12	600	12	65
13	Commission basis	No data	No data
14	Commission basis	No data	No data

The manager should be young enough to appreciate the opportunities offered him by his position. Retired or aged men seldom give satisfaction over long periods of time. Every effort should be made to keep a good manager for as long a period as he can be held by the opportunities which are made possible by the business.

Accounting System

Management cannot be thoroughly efficient without systematic records. Neither car-door associations nor warehouse companies can afford to operate without records which are reasonably complete and actually usuable. Lack of knowledge and interest in the keeping of accurate records is one of the greatest weaknesses of the cooperative warehouses in the state. Much progress is being made, however, by the more successful warhouses in correcting this weakness.

In the case of cooperative companies systematic accounts are required for other reasons than that of merely efficient management. These reasons may be listed as follows:

1. The interests of a large number of people are in the hands of the management. Justice calls for permanent and complete records.

2. Complete records are necessary in order to comply with the State Cooperative Act which requires the payment of patronage dividends. To comply with this provision the amount of patronage by each member must be known.

3. Confidence of the members must be sustained by complete information with regard to all details of the business. Complete records are often necessary to allay unfounded suspicion and distrust.

Many managers are puzzled over the problem of what kind of books to keep and how to keep them. In actual practice the records of the warehouses in the state ranged from the keeping of a day book and a checking account to a complete double entry bookkeeping system which included sales slips, daybook, journal, cash book, and ledger. In place of the common cash book, some managers have recommended the adoption of an income tax record book similar to the one put out by the Greenwood Company, 712 Federal Street, Chicago, Illinois. This type of book automatically gives a monthly and annual balance form if filled out completely.

Unfortunately, accountancy cannot be learned from the various record books and experimentation in keeping records is a rather hazardous business practice. To install a system of accounting the services of an experienced accountant has, as a general rule, proved to be profitable. Moreover, it is a good plan to supply an experienced bookkeeper long enough to thoroughly familiarize the manager with the system. Often a bookkeeper may be employed on a part time basis. Where the manager is kept busy with other work due to a large volume of business, a full time assistant may be hired to keep the books. As a general principle it is never advisable to neglect the bookkeeping needs of the business even though the expense may appear to be excessive.

Making the books effective for the use of the manager, executive committee, and the board of directors requires skill on the part of the bookkeeper and considerable study on the part of those responsible for the management. Two devices for facilitating an analysis of the business are in general use, the balance

sheet and operating statement. The balance sheet should be made use of frequently for it can be calculated from rather limited records. "A balance sheet in an orderly arrangement of assets owned by a business and the claims against it, the purpose of which is to show clearly the financial condition of the business." A sample balance sheet will be found on pages 40 and 41.

An operating statement should be prepared at least once a year, and a quartely statement is very helpful especially for a new business. The operating statement calls for accurate and adequate accounts which are costly, but even so the operating efficiency of the business is so focussed before the manager and directors as to warrant the additional labor and expense. Since the operating statement makes possible a frequent check on the profitableness of the business, and a comparison between succeeding periods and seasons, it points the way to improvements. A sample operating statement, specifically adapted to cooperative companies will be found on pages 44 and 45.

Table 16 shows the frequency of audits, the personnel of the auditors, and the number of inventories per year for the several warehouses covered by this study. An annual audit is the usual practice. Inventories are more frequent and range from 1 to 12 annually. For the cooperative companies audits are of particular significance because of the relation of confidence to the success of the enterprise. The personnel of the auditing committee should always include at least one experienced accountant. Too often an auditing committee selected from members of the company make a hasty examination because of inadequate knowledge of accountancy.

Some members of the executive committee or of the board of directors should, as a rule, be present to participate in the taking of an inventory. This has the advantage of establishing confidence and at the same time of giving the executive committee some very desirable details of the business.

Suggested Balance Sheet

On pages 40 and 41 will be found a suggested balance sheet for cooperative associations, as prepared by the Department of Agricultural Economics of the

TABLE 16.—Number of Audits and Inventories made by Twelve County Farm Bureau Warehouses During the Fiscal Year or Part of Year Covered by This Study.

Warehouse Number in the Order of the Date of Beginning Business	Number of Audits	By Whom the Audits Were Made	Number of Inventories
1	2	President or Manager	2
3	1	Certified Public Accountant	1
4	1	State Extension Service	No data
5	1	Committee of Stockholders	1
6	1	Certified Public Accountant	12
7	1	Another Bookkeeper	1
8	1	Commercial Auditor	2
9	1	State Extension Service	3
10	1	State Extension Service	6
12	1	State Extension Service	2
13	None as yet		None as yet
14	None as yet		None as yet

New York State College of Agriculture at Cornell University, Ithaca, New York.

The items listed on this balance sheet are explained by the department as follows:

ASSETS

1.—CURRENT ASSETS. Includes all assets which are normally to be converted into cast within a period of one year in the ordinary course of business.

2.—*Cash in Bank and on Hand.* All bank deposits. Cash and checks in the safe or till. Cash in transit between offices. Petty cash funds.

3.—*Trade Accounts Receivable.* Open book accounts arising only through sale of merchandise.

4.—*Bad Accounts.* An adequate estimate of the amount of probable uncollectible accounts included in 3.

5.—*Net Trade Accounts Receivable.* Deduct 4 from 3.

6.—*Other Accounts Receivable.* Open book accounts arising through any circumstances except sale of merchandise. Include no doubtful accounts.

7.—*Notes Receivable.* All notes, trade acceptances, or bankers' acceptances which the association holds in satisfaction of accounts due it, including any discounted at the bank with the association's endorsement. Enter notes of doubtful value separately under 12 or 13.

8.—*Discounted Notes.* All notes or acceptances signed by others which the association has discounted bearing its endorsement.

9.—*Net Notes Receivable.* Deduct 8 from 7.

10.—*Merchandise Inventory.* All merchandise purchased for resale, whether paid for or not. Value at cost or market, whichever is lower.

11.—*Accrued Income.* Any items of income accrued in favor of the association, such as interest accrued on notes receivable not yet due or on savings bank account, or rent accrued on property let to others.

12-13.—*Other Assets.* Any other current assets (see 1) not otherwise provided for, such as temporary investments in certificates of indebtedness or other associations or other readily marketable securities, or goods in shipment for which payment has not yet been received.

14.—*Total Current Assets.* Total of 2, 5, 6, 9, 10, 11, 12, and 13.

15.—DEFERRED CHARGES. Includes all services which have not been received and supplies which have not been used up, but for which payment has been made in advance.

16.—*Supplies Inventory.* Stationery, postage stamps, oil, gasoline and grease, waste, car-lining materials, sacks or containers, and other supplies not held for sale.

17.—*Prepaid Insurance.* The share of insurance premiums paid proportionate to the share of time which the policies have yet to run.

18-19.—*Other Deferred Charges.* Any other deferred charges to operations (see 15) such as interest prepaid on notes payable.

20.—*Total Deferred Charges.* Total of 16, 17, 18 and 19.

21.—DEFERRED ORGANIZATION EXPENSE. Expenses of organization or obtaining new members, the benefits of which will last over a long enough period to justify carrying the expenditure involved as an asset to be gradually written off as expense.

22.—*Investments in Companies.* Permanent investments in securities of other companies whose business is related to your own, such as stock in a central association. If it represents a major share of the ownership of any other company, a similar balance sheet should be made out for each company so owned, and a consolidated balance sheet should be prepared.

23.—*Additional Assets.* Any assets not classifiable under any of the other asset headings. List details.

24.—FIXED ASSETS. Includes all assets of a relatively permanent and tangible nature.

25.—*Office Equipment.* The cost value, including freight or truckage and installation expense, of any movable office equipment owned, such as safe, desk, chairs, typewriters, and calculating machines.

26.—*Depreciation.* A liberal deduction for loss in value due to wear and tear.

27.—*Net Office Equipment.* Deduct 26 from 25.

28.—*Delivery Equipment.* Cost value of autos, horses and wagons, and accessories owned and used for delivery purposes.

29.—*Depreciation.* See 26.

30.—*Net Delivery Equipment.* Deduct 29 from 28.

31.—*Warehouse Equipment.* Cost value, including transportation charges and installation expense, of warehouse equipment owned, such as trucks, scales, and machinery of various kinds.

32.—*Depreciation.* See 26.

33.—*Net Warehouse Equipment.* Deduct 32 from 31.

34.—*Buildings.* Cost of all buildings owned for whatever purpose used.

35.—*Depreciation.* See 26.

36.—*Net Value Buildings.* Deduct 35 from 34.

37.—*Land.* Cost of all land owned.

38.—*Total Fixed Assets.* Total of 27, 30, 33, 36, and 37.

39.—*Total Assets.* Total of 14, 20, 21, 22, 23, and 38. In the column for percentages show what percentage each of these items is of the total, which equals 100 percent; this is to help to show how the association's money is invested in assets.

LIABILITIES

1.—CURRENT LIABILITIES. This includes all short term liabilities which become due within one year.

2.—*Accounts Payable.* Debts of the association which are represented only by open book accounts for merchandise purhased for resale.

3.—*Notes to Creditors.* Notes signed by the association or drafts accepted by the association in payment for goods purchased for resale.

4.—*Unsecured Bank Notes.* Notes signed by the association and given to banks for borrowings, not secured by collateral.

5.—*Collateral Bank Notes.* Notes signed by the association and given to banks for borrowings, secured by demand notes of members received by the association for that purpose. In the footnote indicated by the dagger (†) state the total face value of such demand notes of members held for that purpose, whether actually so used at present or not.

6.—*Accrued Interest.* Liabilities to the holders of the association's interest-bearing notes or mortgages on account of interest accrued but not yet payable.

7.—*Taxes Accrued.* An estimate of the amount of income or other taxes which is chargeable to the operations of the period ending at the date of this balance sheet.

8-13.—*Other Liabilities.* Any other current liabilities (see 1) such as wages earned but not paid, dividends declared, or interest accrued on Certificates of Indebtedness.

14.—*Total Liabilities.* Total of 2 to 13.

15.—FIXED LIABILITIES. Includes liabilities of duration of more than one year to others than members.

16.—*Mortgages.* Mortgages on real estate or other property owned by the association.

17.—*Unsecured Loans.* Long term borrowings not secured by mortgages.

18.—*Other Liabilities.* Any other fixed liability (see 15).

19.—*Total Fixed Liabilities.* Total of 16, 17, and 18.

20.—MEMBERSHIP LIABILITIES. Includes all capital represented by long term obligations to members.

21.—*Certificates of Indebtedness.* Face value of Certificates of Indebtedness issued to members and outstanding.

22.—*Certificates Unissued.* Amount deducted from accounts due members for which Certificates of Indebtedness are to be issued.

23.—*Certificates of Interest.* Face value of Certificates of Interest issued to members and outstanding.

24.—*Other Liabilities.* Any other membership liabilities (see 20).

25.—*Total Membership Liabilities.* Total of 21, 22, 23, and 24.

26.—NET WORTH. The owners' share in the assets of the association over and above any interest in the assets represented by Certificates of Indebtedness or Certificates of Interest.

27.—*Preferred Stock.* Par value of preferred capital stock issued and outstanding.

28.—*Common Stock.* Par value of common capital stock issued and outstanding.

29.—*Contingency Reserve.* The amount of capital reserved to cover any extraordinary losses not due to the ordinary operations of the association.

30.—*Other Items.* Any other items of net worth (see 26) not enumerated.

31.—*Surplus.* Unapportioned income which may be divided later.

32.—*Total Net Worth.* Total of 27, 28, 29, 30, and 31.

33.—*Total Liabilities and Capital.* Total of 14, 19, 25, and 32. If all entries have been properly made, this total should equal 39 on the assets side. In the column for percentages show what percentage each of these items is of the total, which equals 100 percent; this is to show the sources of capital used by the association.

SUGGESTED BALANCE SHEET*

ASSETS

1.	**CURRENT ASSETS:**				
2.	Cash in Bank and on Hand		$......		
3.	Accounts Receivable, Trade	$......			
4.	Less Allowance for Bad Accounts	....			
5.	Net Trade Accounts Receivable		....		
6.	Accounts Receivable, Other		....		
7.	Notes Receivable	....			
8.	Less Notes Receivable Discounted	....			
9.	Notes Receivable, Net		....		
10.	Merchandise Inventory		....		
11.	Accrued Income		....		
12.	....		....		
13.	....		....		
14.	**Total Current Assets**			$......	%
15.	**DEFERRED CHARGES TO OPERATIONS:**				
16.	Supplies Inventory		....		
17.	Insurance Prepaid		....		
18.	....		....		
19.	....		....		
20.	**Total Deferred Charges to Operations**			....	%
21.	**DEFERRED ORGANIZATION EXPENSE**			....	%
22.	**INVESTMENTS IN RELATED COMPANIES**			....	%
23.	....			....	%
24.	**FIXED ASSETS:**				
25.	Office Equipment	....			
26.	Less Allowance for Depreciation	....			
27.	Office Equipment, Net		....		
28.	Delivery Equipment	....			
29.	Less Allowance for Depreciation	....			
30.	Delivery Equipment, Net		....		
31.	Warehouse Equipment	....			
32.	Less Allowance for Depreciation	....			
33.	Warehouse Equipment, Net		....		
34.	Buildings	....			
35.	Less Allowance for Depreciation	....			
36.	Buildings, Net		....		
37.	Land		....		
38.	**Total Fixed Assets**			....	%
39.	**TOTAL ASSETS**			$......	100%

LIABILITIES AND CAPITAL

1. **CURRENT LIABILITIES:**			
2. Accounts Payable	$......		
3. Notes Payable to Trade Creditors	....		
4. Notes Payable to Bank, Unsecured	....		
5. Notes Payable to Bank, Collateral Demand Notes†	....		
6. Interest Expense Accrued	....		
7. Taxes Accrued	....		
8.	....		
9.	....		
10.	....		
11.	....		
12.	....		
13.	....		
14. **Total Current Liabilities**		$......	%
15. **FIXED LIABILITIES:**			
16. Mortgages Payable	....		
17. Unsecured Long Term Loans	....		
18.	....		
19. **Total Fixed Liabilities**		....	%
20. **MEMBERSHIP LIABILITIES:**			
21. Certificates of Indebtedness Issued	....		
22. Deductions for Certificates Unissued	....		
23. Certificates of Interest Issued	....		
24.	....		
25. **Total Membership Liabilities**		....	%
26. **NET WORTH:**			
27. Capital Stock, Preferred	....		
28. Capital Stock, Common	....		
29. Reserve for Contingencies	....		
30.	....		
31. Surplus	....		
32. **Total Net Worth**		....	%
33. **TOTAL LIABILITIES AND CAPITAL**		$......	100%

†Note.—Total Demand Notes of Members held $......

*Marketing Blank No. 4 for Cooperative Purchasing and Selling Associations prepared by Department of Agricultural Economics, New York State College of Agriculture at Cornell University, Ithaca, N. Y.

Suggested Operating Statement

A suggested operating statement is given on pages 44 and 45 for cooperative producing and selling associations. This blank is the form prepared and used by the Department of Agricultural Economics of the New York State College of Agriculture at Cornell University, Ithaca, New York.

The department gives the following explanation of the items listed on the operating statement:

1.—*Gross Sales Produce.* Total sales of produce at billed price.

2.—*Allowances.* Amount of allowances made to purchasers on account of damaged produce or other claims.

3.—*Icing and Freight.* Cost of icing cars and freight to destination if paid by the association.

4.—Net Sales. Deduct the total of 2 and 3 from 1.

5.—Payments to Members. The amount paid to members for the produce sold for them. Show in the space provided what percentage this item is of item 4.

6.—Gross Margin. Deduct 5 from 4.

7.—*Gross Sales Supplies.* Total sales of merchandise at billed price.

8.—*Returns and Allowances.* Amount of allowances made to purchasers on account of damaged goods or quanity purchases or goods returned.

9.—*Cash Discounts.* Amount of discounts allowed to purchasers for prompt payment.

10.—Net Sales Supplies. Deduct the total of 8 and 9 from 7.

11.—*Inventory.* Inventory of merchandise on hand at the beginning of the year, valued at cost or market price, whichever is lower. Do not include merchandise held on consignment.

12.—*Purchases.* Billed cost of merchandise purchased during the year.

13.—*Transportation.* Cost of getting merchandise purchased to the warehouse by freight, express, or hauling.

14.—*Gross Purchases.* Total of 12 and 13.

15.—*Returns and Allowances.* Amount of allowances received on purchases for damaged or returned goods.

16.—*Discounts Received.* Amount of discounts received for prompt payment on purchases of merchandise.

17.—*Net Cost Purchases.* Deduct the total of 15 and 16 from 14.

18.—*Supplies Handled.* Total of 11 and 17.

19.—*Final Inventory.* Inventory and merchandise on hand at end of year, valued at cost or market price, whichever is lower. Do not include merchandise held on consignment.

20.—Supplies Sold. Deduct 19 from 18. This is the net cost of the merchandise which has been sold during the year. Show in the space provided what percentage this item is of item 10.

21.—Gross Margin Supplies. Deduct 20 from 10.

22.—Total Gross Margin. Total of 6 and 21. This is the margin allowed out of which expenses must be paid, reserves set up, and working capital accumulated.

23.—*Manager's Salary.* Amount paid the manager for his services, exclusive of expenses (such as traveling) paid for him.

24.—*Labor Wages.* Total amount paid for labor.

25.—*Office Salaries.* Total amount paid for clerical work.

26.—*Unclassified Wage.* Other wages and salaries.

27.—*Total for Employees.* Total of 23, 24, 25, and 26.

28.—*Rent.* The amount paid as rent for all lands and buildings used by the association.

29.—*Depreciation.* If the buildings are owned instead of rented, a liberal estimate of the decrease in value due to wear and tear during the year.

30.—*Repairs.* The cost of all repairs to the buildings owned by the association; do not include additions or improvements in this item.

31.—*Insurance.* The share of the premiums for fire and storm insurance on the buildings paid for the current year only; do not include premiums paid for insurance covering any other period.

32.—*Taxes.* All taxes assessed or estimated to be assessed for the current year on land and buildings owned by the association.

33.—*Other Maintenance.* Any other expense of maintaining the land and buildings of the association.

34.—*Real Estate Expense.* The total of 28, 29, 30, 31, 32, and 33.

35.—*Equipment Depreciation.* A liberal estimate for decrease in value of equipment, such as machinery, tools, and furniture.

36.—*Equipment Repairs.* The cost of all repairs to the equipment; do not include additions or improvements in this item.

37.—*Supplies.* The cost of all warehouse and loading supplies such as sacks and twine, lumber and paped for carlining, and bulkheads, used during the year.

38.—*Demurrage.* Railroad charges for demurrage alone; do not include this in item 3 as freight.

39.—*Inspection.* Cost of inspecting produce at shipping or terminal points. If done by the employees of the association, their salaries and expenses.

40.—*Utilities.* Cost of heating and power, and charges for water and lighting service.

41.—*Communication.* Charges for telephone and telegraph service.

42.—*Office Supplies.* Cost of all office supplies, such as stationery, twine, miscellaneous supplies, and postage, used during the period.

43.—*Bank Exchange.* Charges for collection of drafts and out-of-town checks. Do not include interest on borrowed capital which should go under 49, or protest fees which should be entered separately.

44.—*Travel.* Total expenses of employees when traveling in the interest of the association.

45.—*Fees.* Amount of commission and brokerage fees paid by the association for handling the sale of its produce.

46.—*Bad Accounts.* Amount of accounts receivable uncollectible or estimated to be uncollectible.

47.—*Legal Expense.* Amount paid for legal advice and services.

48. *Licenses.* Taxes on personal property or on the association, and license fees paid to the state.

49.—*Interest.* The amount of interest incurred for the use of borrowed capital duaing the year.

50, 51, 52, 53.—*Unclassified Expenses.* Any other expenses incurred in the normal operations of the business, with the larger items stated separately.

54.—*Total Office and General Expense.* Total of 35 to 53, inclusive.

55.—TOTAL OPERATING EXPENSE. Total of 27, 34, and 54.

56.—NET OPERATING INCOME. Deduct 55 from 22. This is the net amount due to members after deducting the cost of the merchandise, all operating expenses, and the amount already paid to members.

57.—*Membership Fees.* Amount paid the association by new members for the privilege of joining the association.

58.—*Annual Dues.* Amount of annual dues paid the association by its members.

59.—*Interest Income.* Interest earned on accounts or notes receivable or money loaned to others during the period.

60.—*Miscellaneous Income.* Any other items of miscellaneous income to the association.

61.—*Total Other Incomes.* Total of 57, 58, 59, and 60.

62.—NET INCOME FOR DISTRIBUTION. Total of 56 and 61. This is the net amount available to pay interest on Certificates of Indebtedness, dividends on stock or patronage basis, to provide a reserve for contingencies, or to be kept in the association as an operating fund represented by Certificates of Interest or Certificates of Indebtedness.

63.—*Accrued Interest.* Interest accrued on Certificates of Indebtedness during the year.

64.—*Stock Dividends.* Dividends declared on capital stock.

65.—*Patronage Dividends.* Patronage dividend declared.

66.—*Reserve.* Amount set up as a reserve for unexpected losses which are not part of the regular operating expenss of the association.

67.—*Certificates of Indebtedness.* The face value of Certificates of Indebtedness issued against deductions from payments to members on this year's business, and the amount of deductions against which Certificates will later be issued.

68.—*Certificates of Interest.* The face value of Certificates of Interest issued against the income from the business of the current year.

69.—*Total Distributed Income.* Total of 63 to 68, inclusive.

70.—*Undivided Surplus.* Deduct 69 from 62. This is the amount to be carried over to be distributed during the following year.

In the column for percentages enter the percentage which each item is of the total of items 4 and 10.

SUGGESTED OPERATING STATEMENT*

1. Gross Sales of Produce			$......		
2. Less: Allowances to Customers		$.......			
3. Icing and Freight Out		....	....		
4. NET SALES OF PRODUCE			....		
5. PAYMENTS TO MEMBERS FOR PRODUCE (........% of Net Sales of Produce)			....		
6. GROSS MARGIN ON PRODUCE				$......	%
7. Gross Sales of Supplies			....		
8. Less: Returns and Allowances		....			
9. Cash Discounts Allowed		....	....		
10. NET SALES OF SUPPLIES			....		
11. Supplies Inventory at Beginning		....			
12. Purchase of Supplies	$......				
13. Freight, Express, and Cartage	....				
14. Gross Cost of Purchases	....				
15. Less: Returns and Allowances	....				
16. Cash Discounts Received	....				
17. Net Cost of Purchases		....			
18. Cost of Supplies Handled		....			
19. Supplies Inventory at End		....			
20. COST OF SUPPLIES SOLD (........% of Net Sales of Supplies)			....		
21. GROSS MARGIN ON SUPPLIES				....	%
22. TOTAL GROSS MARGIN				....	%
23. Manager's Salary		....			
24. Wages of Labor		....			
25. Office Salaries		....			
26.		....			
27. Total Salaries and Wages			....		%
28. Rent of Land and Buildings		....			
29. Depreciation of Buildings		....			
30. Repairs of Buildings		....			
31. Insurance on Buildings		....			
32. Taxes on Land and Buildings		....			
33.		....			
34. Total Real Estate Expense			....		%

35. Depreciation of Equipment	$......			
36. Repairs of Equipment	....			
37. Warehouse and Loading Supplies	....			
38. Demurrage	....			
39. Inspection Expense	....			
40. Heat, Light, Power, and Water	....			
41. Telephone and Telegraph	....			
42. Office Supplies and Postage	....			
43. Bank Exchange	....			
44. Traveling Expense	....			
45. Commissions and Brokerage	....			
46. Loss from Bad Debts	....			
47. Legal Expense	....			
48. General Taxes and Licenses	....			
49. Interest on Borrowed Capital	....			
50.	....			
51.	....			
52.	....			
53.	....			
54. **Total Office and General Expense**		$......		%
55. **TOTAL OPERATING EXPENSE**			$......	%
56. **NET OPERATING INCOME**			....	%
57. Membership Fees		....		
58. Annual Dues		....		
59. Interest Income		....		
60.		....		
61. **Total Other Income**			......	
62. **NET INCOME FOR DISTRIBUTION**			......	%
Disposition of Net Income:				
63. Interest on Certificates of Indebtedness		....		
64. Dividend on Capital Stock		....		
65. Patronage Dividend		....		
66. Carried to Reserve for Contingencies		....		
67. Certificates of Indebtedness Issued		....		
68. Certificates of Interest Issued		....		
69. **Total Distributed Income**			.....	%
70. **Undivided Surplus**			....	

*Marketing Blank No. 1 for Cooperative Associations, prepared by Department of Agricultural Economics, New York State College of Agriculture at Cornell University, Ithaca, N. Y.

WEST VIRGINIA COOPERATIVE MARKETING ACT OF 1923

A BILL to amend and re-enact chapter one hundred and twenty-one of the acts of the legislature of one thousand nine hundred and twenty-one, regular session all relating to the authorization and the formation of non-profit, cooperative associations, with or without capital stock, for the purpose of encouraging the orderly marketing of agricultural products through cooperation defining the various terms used therein; enumerating the activities and powers of such an association; prescribing the rights and privileges of membership; providing for articles of incorporation, declaring what they shall contain, manner of executing and filing, method of amending same; providing for by-laws and what they may contain; providing for method of election of directors, filling of vacancies, powers and duties of directors, division into election districts, appointment of executive committees, and allotment of functions and powers; providing for officers, qualifications, election and function; regulating issuance of membership certificates of stock and payment thereof; limiting personal liability of members for debts of association; regulating voting power of members and stock holders; authorizing issuance of preferred stock, with or without right to vote, and the retirement thereof; providing for removal of officers and directors; providing for referendum to members; providing for a marketing contract, and prescribing remedies for breach of contract, including liquidated damages, fees, and all costs; authorizing injuction and general equitable remedies in the event of breach of agreement; stating presumption of control of products by landlords who have signed marketing agreements; providing for annual reports; providing that no provision of law in conflict with this act shall be construed as applying to such associations; providing that legal exemption of agricultural products in the possession of producers shall apply to such products in possession of, or under the control of, such associations; limiting the use of the word "cooperative" in names for producers, cooperative marketing activities; and prescribing a penalty for violating such inhibition; permitting associations to organize other corporations or to own stock in other corporations; providing for agreements with other cooperative associations in this or other states and stating the purposes or reasons therefor; providing that associations heretofore organized may re-organize hereunder; providing for similar rights and remedies for cooperative associations organized under generally similar laws in other states; making it a misdemeander to induce a member to breach his marketing contract with the association, or spread false reports about it and prescribing a fine for each offense; making such offender liable to the association for a prescribed penalty therefor in a civil suit; providing liability to the association in a penal sum in certain cases for any person who knowingly solicits, persuades, or permits any member of the association to breach his marketing contract; authorizing an injuction against such warehouseman; and providing for payment of all fees and costs; and setting out the reasons for such provisions; providing that no such association shall be deemed a conspiracy or an illegal combination or monopoly; providing that marketing contracts shall not be considered illegal; providing that if any section of this act shall be declared unconstitutional, the remainder of the act shall not be thereby affected; providing that the general corporation laws of this state shall apply to such associations, except where inconsistent with express provisions hereof; providing for annual license fees; providing fees for filing articles of incorporation and amendments thereto; providing that this act may be hereafter indexed and cited as "The Cooperative Marketing Act;" and declaring an emergency to exist.

Be it enacted by the Legislature of West Virginia:

That chapter one hundred and twenty-one of the acts of the legislature of one thousand nine hundred and twenty-one be amended and re-enacted to read as follows:

Declaration of Policy

Section 1. In order to promote, foster, and encourage the intelligent and orderly marketing of agricultural products through cooperation; to eliminate speculation and waste; to make the distribution of agricultural products between producer and consumer as direct as can be efficiently done; to stabilize the marketing of agriculture products; and to provide for the organization and incorporation of cooperative marketing associations for the marketing of such products, this act is passed.

Definitions as Used in This Act

Section 2. (a) The term "agricultural products" shall include horticultural, viticultural, forestry, dairy, livestock, bee, and any other farm products.

(b) The term "member" shall include actual members of associations without capital stock and holders of common stock in associations organized with capital stock.

(c) The term "association" means any corporation organized under this act;and

(d) the term "person" shall include individuals, firms, partnerships, corporations, and associations.

Associations organized hereunder shall be deemed "non-profit," inasmuch as they are not organized to make profit for themselves, as such, or for their members, as such but only for their members as producers.

(e) For the purposes of brevity and convenience this act may be indexed, referred to and cited as "The Cooperative Marketing Act."

Who May Organize

SECTION 3. Eleven or more persons, a majority of whom are residents of this state, engaged in the production of agricultural products, may form a non-profit, cooperation association, with or without capital stock, under the provisions of this act.

Purposes

SECTION 4. An association may be organized to engage in any activity in connection with the marketing or selling of the agricultural products of its members, or with the harvesting, preserving, drying, processing, canning, packing, grading, storing, handling, shipping, or utilization thereof, or the manufacturing or marketing of the by-products thereof, or in connection with the manufacturing, selling, or supplying to its members of machinery, equipment, or supplies; or in the financing of the foregoing enumerated activities; or in any one or more of the activities specified herein.

Preliminary Investigation

SECTION 5. Every group of persons contemplating the organization of an association under this act is urged to communicate with the Dean of the College of Agriculture, West Virginia University, at Morgantown, who will inform them whatever a survey of the marketing conditions affecting the commodities proposed to be handled may indicate regarding probable success.

It is here recognized that agriculture is characterized by individual production in contrast to the group or factory system that characterizes other forms of industrial production; and that the ordinary form of corporate organization permits industrial groups to combine for the purpose of group production and the ensuing group marketing and that the public has an interest in permitting farmers to bring their industry to the high degree of efficiency and merchandising skill evidenced in the manufacturing industries; and that the public interest urgently needs to prevent the migration from the farm to the city in order to keep up farm production and to preserve the agricultural supply of the nation; and that the public-interest demands that the farmer be encouraged to attain a superior and more direct system of marketing in the substitution of merchandising for the blind, unscientific, and speculative selling of crops; and that for this purpose, the farmers should obtain special guidance and instructive data from the Dean of the College of Agriculture, West Virginia University, Morgantown.

Powers

SECTION 6. Each association incorporated under this act shall have the following powers:

(a) To engage in any activity in connection with the marketing, selling, preserving, harvesting, drying, processing, manufacturing, canning, packing, grading, storing, handling, or utilization of any agricultural products produced or delivered to it by its members, or the manufacturing or marketing of the by-products thereof; or any activity in connection with the purchase, hiring or use by its members of supplies, machinery or equipment; or in the financing of any such activities; or in any one or more of the activities specified in this section. No association, however, shall handle the agricultural products of any non-member, except for storage.

(b) To borrow money without limitation as to amount of corporate indebtedness or liability; and to make advance payments and advances to members.

(c) To act as the agent or representative of any member or members in any of the foregoing mentioned activities.

(d) To purchase or otherwise acquire, and to hold, own, and exercise all rights of ownership, in, and to sell, transfer, or pledge, or guarantee the payment of dividends or interest on, or the retirement or redemption of, shares of the capital stock or bonds of any corporation or association engaged in any related activity or in the warehousing or handling or marketing of any of the products handled by the association.

(e) To establish reserves and to invest the funds thereof in bonds or n such other property as may be provided in the by-laws.

(f) To buy, hold, and exercise all privileges of ownership, over real or personal property as may be necessary or convenient for the conduct and operation of any of the business of the association, or incidental thereto.

(g) To establish, obtain, own, and develop patents, trademarks, and copyrights.

(h) To do each and every thing necessary, suitable, or proper for the accomplishment of any one of the purposes or the attainment of any one or more of the subjects herein enumerated, or conducive to or expedient for the interest or benefit of the association, and to contract accordingly; and in addition to exercise and possess all powers, rights, and privileges necessary or incidental to the purposes for which the association is organized or to the activities in which it is engaged; and in addition, any other rights, powers, and privileges granted by the laws of this state to ordinary corporations, except such as are inconsistent with the express provisions of this act; and to do any such thing anywhere.

Members

SECTION 7. (a) Under the terms and conditions prescribed in the by-laws adopted by it, an association may admit as members, (or issue common stock to), only persons engaged in the production of the agricultural products to be handled by or through the association, including the lessees and tenants of land used for the production of such products and any lessors and landlords who receive as rent all or any part of the crop raised on the leased premises.

(b) If a member of a non-stock association be other than a natural person, such member may be represented by any individual, associate, officer, or manager or member thereof, duly authorized in writing.

(c) One association organized hereunder may become a member or stockholder of any other association or associations organized hereunder.

Articles of Incorporation

SECTION 8. Each association formed under this act must prepare and file articles of incorporation, setting forth:

(a) The name of the association.

(b) The purposes for which it is formed.

(c) The place where its principlal business will be transacted.

(d) The term for which it is to exist, not exceeding fifty years.

(e) The number of directors thereof, which must be not less than five and may be any number in excess thereof; the terms of office of such directors; and the names and addresses of those who are to serve as incorporation directors for the first term, or until the election and qualification of their successors.

(f) If organized without capital stock, whether the property rights and interest of each member shall be equal or unequal; and if unequal, the general rule or rules applicable to all members by which the property rights and interests, respectively, of each member may and shall be determined and fixed; and provision for the admission of new members who shall be entitled to share in the property of the association with the old members, in accordance with such general rule or rules. This provision or paragraph of the articles of incorporation shall not be altered, amended, or repealed except by the written consent or vote of three-fourths of the members.

(g) If organized with capital stock, the amount of such stock and the number of shares into which it is divided and the par value thereof.

The capital stock may be divided into preferred and common stock. If so divided, the articles of incorporation must contain a statement of the number of shares of stock to which preference is granted and the number of shares of stock to which no preference is granted and the nature and definite extent of the preference and privileges granted to each.

The articles must be subscribed by the incorporators and acknowledged by one of them before an officer authorized by the law of the state to take and certify acknowledgements of deeds and conveyances; and shall be filed in accordance with the provisions of the general corporation law of this state; and when so filed, the said articles of incorporation, or certified copies thereof, shall be received in all the courts of this state and other places as prima facie evidence of the facts contained therein and of the due incorporation of such association. *A certified copy of the articles of incorporation shall also be filed with the Dean of the College of Agriculture, West Virginia University, Morgantown, West Virginia.*

Amendments to Articles of Incorporation

SECTION 9. The articles of incorporation may be altered or amended at any regular meeting or any special meeting called for that purpose. An amendment must first be approved by two-thirds of the directors and then adopted by a vote representing a majority of all the members of the association. Amendments to the articles of incorporation, when so adopted, shall be filed in accordance with the provisions of the general corporation law of this state.

By-Laws

SECTION 10. Each association incorporated under this act must, within thirty days after its incorporation, adopt for its government and management, a code of by-laws, not inconsistent with the powers granted by this act. A majority vote of the members or stockholders, or their written assent, is necessary to adopt such by-laws. Each association, under its by-laws, may provide for any or all of the following matters:

(a) The time, place, and manner of calling and conducting its meetings.

(b) The number of stockholders or members constituting a quorum.

(c) The right of members or stockholders to vote by proxy or by mail or both; and the conditions, manner, form, and effects of such votes.

(d) The number of directors constituting a quorum.

(e) The qualifications, compensation, and duties and term of office of directors and officers; time of their election and the mode and manner of giving notice thereof.

(f) Penalties for violation of the by-laws.

(g) The amount of entrance, organization, and membership fees, if any; the manner and method of collection of the same; and the purposes for which the may be used.

(h) The amount which each member or stockholder shall be required to pay annually or from time to time, if at all, to carry on the business of the association; the charge, if any, to be paid by each member or stockholder for services rendered by the association to him and the time of payment and the manner of collection; and the marketing contract between the association and its members or stockholders which every member or stockholder may be required to sign.

(i) The number and qualifications of members or stockholders of the association and the conditions precedent to membership or ownership of common stock; the method, time, and manner of permitting members to withdraw or the holders of common stock to transfer their stock; the manner of assignment and transfer of the interest of members and of the shares of common stock; the conditions upon which and time when membership of any member shall cease; the automatic suspension of the rights of a member when he ceases to be eligible to membership in the association; and the mode, manner, and effect of the expulsion of a member; the manner of determining the value of a member's interest and provision for its purchase by the association upon the death or withdrawl of a member or stockholder, or upon the expulsion of a member or forfeiture of his membership, or, at the option of the association, the purchase at a price fixed by conclusive appraisal by the board of directors. In case of the withdrawal or expulsion of a member, the board of directors shall equitably and conclusively appraise his property interests in the association and shall fix the amount thereof in money, which shall be paid to him within one year after such expulsion or withdrawal.

General and Special Meetings—How Called

SECTION 11. In its by-laws, each association shall provide for one or more regular meetings annually. The board of directors shall have the right to call a special meeting at any time; and ten percent of the members or stockholders may file a petition stating the specific business to be brought before the association and demand a special meeting at any time. Such meeting must thereupon be called by the directors. Notice of all meetings, together with a statement of the purposes thereof, shall be mailed to each member at least ten days prior to the meeting; provided, however, that the by-laws may require instead that such notice may be given by publication in a newspaper of general circulation, published at the principal place of business of the association.

Directors—Election

SECTION 12. The affairs of the association shall be managed by a board of not less than five directors, elected by the members or stockholders from their own number. The by-laws may provide that the territory in which the association has members shall be divided into districts and that the directors shall be elected according to such districts, either directly or by district delegates elected by the members in that district. In such a case the by-laws shall specify the number of directors to be elected by each district, the manner and the method of reapportioning the directors and of redistricting the territory covered by the association. The by-laws

may provide that primary elections shall be held in each district to elect the directors apportioned to such districts and that the results of all such primary elections may be ratified by the next regular meeting of the association or may be considered final as to the association. The by-laws may provide that one or more directors may be appointed by any public official or commission or by the other directors selected by the members or their delegates. Such directors shall represent primarily the interest of the general public in such associations. The directors so appointed need not be members or stockholders of the association; but shall have the same powers and rights as other directors. Such directors shall not number more than one-fifth of the entire number of directors.

An association may provide a fair remuneration for the time actually spent by its officers and directors in its service and for the service of the members of its executive committee. No director, during the term of his office, shall be a party to a contract for profit with the association differing in any way from the business relations accorded regular members or holders of common stock of the association or other, or differing from terms generally current in that district.

The by-laws may provide that no director shall occupy any position in the association, except the president and secretary on regular salary or substantially full time pay.

The by-laws may provide for an executive committee and may allot to such committee all the functions and powers of the board of directors, subject to the general direction and control of the board.

When a vacancy on the board of directors occurs other than by expiration of term, the remaining members of the board, by a majority vote, shall fill the vacancy, unless the by-laws provide for an election of directors by districts. In such a case, the board of directors shall immediately call a special meeting of the members or stockholders in that district to fill the vacancy.

Election of Officers

Section 13. The directors shall elect from their number a president and one or more vice-presidents. They shall also elect a secretary and a treasurer, who need not be directors or members of the association; and they may combine the two latter offices and desigate the combined office as secretary-treasurer; or unite both functions and titles in one person. The treasurer may be a bank or any depository, and as such, shall not be considered as an officer, but as a function of the board of directors. In such case, the secretary shall perform the usual accounting duties of the treasurer, excepting that the funds shall be deposited only as and where authorized by the board of directors.

Officers, Employees, and Agents to Be Bonded

Section 14. Every officer, employee and agent handling funds or negotiable instruments or property of or for any association created hereunder shall be required to execute and deliver adequate bonds for the faithful performance of his duties and obligations.

Stock—Membership Certificates—When Issued—Voting—Liability Limitations on Transfer and Ownership

Section 15. When a member of an association established without capital stock has paid his membership fee in full, he shall receive a certificate of membership.

No association shall issue stock to a member until it has been fully paid for. The promissory notes of the members may be accepted by the association as full or partial payment. The association shall hold the stock as security for the payment of the note; but such retention as security shall not effect the member's right to vote.

No member shall be liable for the debts of the association to an amount exceeding the sum remaining upaid on his membership fee or his subscription to the capital stock, including any unpaid balance on any promissory notes given in payment thereof.

No stockholder of a cooperative association shall own more than one-twentieth of the common stock of the association; and an association, in its by-laws, may limit the amount of common stock which one member may own to any amount less than one-twentieth of the common stock.

No member or stockholder shall be entitled to more than one vote, regardless of the number of shares of common stock owned by him.

Any association organized with the stock under this act may issue preferred stock, with or without the right to vote. Such stock may be sold to any person, member or non-member, and may be redeemable or retireable by the association on such terms and conditions as may

be provided for by the articles of incorporation and printed on the face of the certificate. The by-laws shall prohibit the transfer of the common stock of the association to persons not engaged in the production of agricultural products handled by the association; and such restrictions must be printed upon every certificate of stock subject thereto.

The association may, at any time, as specified in the by-laws, except when the debts of the association exceed fifty percent of the assets thereof, buy in or purchase its common stock at the book value thereof, as conclusively determined by the board of directors, and pay for it in cash within one year thereafter.

Removal of Officers or Directors

SECTION 16. Any member may bring charges against an officer or director by filing them in writing with the secretary of the association, together with a petition signed by five percent of the members, requesting the removal of the officer or director in question. The removal shall be voted upon at the next regular or special meeting of the association and, by a vote of a majority of the members, the association may remove the officer or director and fill the vacancy. The director or officer, against whom such charges have been brought shall be informed in writing of the charges previous to the meeting and shall have an opportunity at the meeting to be heard in person or by counsel and to present witnesses; and the person or persons bringing the charges against him shall have the same opportunity.

In case the by-laws provide for election of directors by districts with primary elections in each district, then the petition for removal of a director must be signed by twenty percent of the members residing in the district from which he was elected. The board of directors must call a special meeting of the members residing in that district to consider the removal of the directors; and by a vote of the majority of the members of that district, the director in question shall be removed from office.

Referendum

SECTION 17. Upon demand of one-third of the entire board of directors, made immediately and so recorded, at the same meeting at which the original motion was passed, any matter of policy that has been approved or passed by the board must be referred to the entire membership or the stockholders for decision at the next special or regular meeting; and a special meeting may be called for the purpose.

Marketing Contract

SECTION 18. The association and its members may take and execute marketing contracts, requiring the members to sell, for any period of time, not over ten years, all or any specified part of their agricultural products or specified commodities exclusively to or through the association, or any facilities to be created by the association. If they contract a sale to the association, it shall be conclusively held that title to the products passes absolutely and unreservedly, except for recorded liens, to the association upon delivery; or at any other specified time if expressly and definitely agreed in the said contract. The contract may provide, among other things, that the association may sell or resell the products delivered by its members, with or without taking title thereto; and pay over to its members the re-sale price, after deducting all necessary selling, overhead, and other costs and expenses, including interest or dividends on stock, not exceeding eight percent per annum, and reserves for retiring the stock, if any; and other proper re-serves; or any other deductions.

Remedies for Breach of Contract

SECTION 19. (a) The by-laws or the marketing contract may fix, as liquidated damages, specific sums to be paid by the members or stockholders to the association upon the breach by him of any provision of the marketing contract regarding the sale or delivery or withholding of products; and may further provide that the member will pay all costs, premiums for bonds, expenses and fees, in case any action in which it shall prevail, brought upon the contract by the association; and any such provisions shall be valid and enforceable in the courts of this state; and such clauses providing for liquidated damages shall be enforceable as such and shall not be regarded as penalties.

(b) In the event of any such breach or threatened breach of such marketing contract by a member, the association shall be entitled to an injunction to prevent the further breach of the contract and to a decree of specific performance thereof. Pending the adjudication of such an action and upon filing a verified complaint showing the breach or threatened breach, and upon filing a sufficient bond, the association may be entitled to a temporary restraining order and preliminary injunction against the member.

(c) In any action upon such marketing agreement, it shall be presumed as between the parties that the landowner or landlord or lessor claiming therein so to be, is able to control the delivery of products produced on his land by tenants or others, whose tenancy or possession or work on such land or the terms of whose tenancy or possession or labor thereon were created or changed after execution by the landowner or landlord or lessor of such a marketing agreement; and in such actions, the foregoing remedies for non-delivery or breach shall lie and be enforceable against such landowner, landlord, or lessor.

Purchasing Business of Other Associations, Persons, Firms or Corporations—Payment—Stock Issued

Section 20. Whenever an association, organized hereunder with preferred capital stock, shall purchase the stock or any property, or any interest in any property of any person, firm or corporation or association, it may discharge the obligations so incurred, wholly or in part, by exchanging for the acquired interest, shares of its preferred capital stock to an amount which at par value would equal the fair market value of the stock or interest so purchased, as determined by the eleven members of the board of directors. In that case the transfer to the association of the stock or interest purchased shall be equivalent to payment in cash for the share of stock issued.

Annual Reports

Section 21. Each association formed under this act shall prepare and make out an annual report on forms to be furnished by the Dean of the College of Agriculture, West Virginia University, Morgantown, containing the name of the association; its principal place of business; and a general statement of its business operations during the fiscal year, showing the amount of capital stock paid up and the number of stockholders of a stock association or the number of members and amount of membership fees received, if a non-stock association; the total expenses of operations; the amount of its indebtedness or liabilities, and its balance sheets.

Conflicting Laws Not to Apply

Section 22. Any provisions of law which are in conflict with this act shall be construed as not applying to the association herein provided for.

Any exemptions whatsoever under any and all existing laws applying to agricultural products in the possession or under the control of the individual producer, shall apply similarly and completely to such products delivered by its former members, in the possession or under the control of the association.

Limitation of the Use of Term "Cooperative"

Section 23. No person, firm, corporation, or association, hereafter organized applying to do business in this state as a farmers' marketing association for the sale of farm products, shall be entitled to use the word "cooperative" as part of its corporate or orther business name or title, unless it has complied with the provisions of this act.

Interest in Other Corporations or Associations

Section 24. An association may organize, form, operate, own, control, have interest in, own stock of, or be a member of any other corporation or corporations, with or without capital stock, and engage in preserving, drying, processing, canning, packing, storing, handling, shipping, utilizing, manufacturing, or selling of the agricultural products handled by the association, or the by-products thereof.

If such corporations are warehousing corporations, they may issue legal warehouse receipts to the association against the commodities delivered by it, or to any other person and such legal warehouse receipts shall be considered as adequate collateral to the extent of the usual and current value of the commodity represented thereby. In case such warehouse is licensed or licensed and bonded under the laws of this or any other state or the United States, its warehouse receipt delivered to the association on commodities of the association or its members, or delivered by the association or its members, shall not be challenged or discriminated against because of ownership or control, wholly or in part, by the association.

Contracts and Agreements With Other Associations

SECTION 25. Any association may, upon resolution adopted by its board of directors, enter into all necessary and proper contracts and agreements and make all necessary and proper stipulations, agreements, contracts, and arrangements with any other cooperative corporation, association or associations, formed in this or in any other state, for the cooperative and more economical carrying on of its business or any part or parts thereof. Any two or more associations may, by agreement, unite in employing and using or may separately employ and use the same personnel, methods, means, and agencies for carrying on and conducting their respective business.

Rights and Remedies Apply to Similar Associations of Other States

SECTION 26. Any corporation or association heretofore or hereafter organized under generally similar laws of another state shall be allowed to carry on any proper activities, operations and functions in this state upon compliance with the general regulations applicable to foreign corporations desiring to do business in this state and all contracts which could be made by any association incorporated hereunder, made by or with such associations shall be legal and valid and enforceable in this state with all of the remedies set forth in this act.

Associations Heretofore Organized May Adopt the Provisions of This Act

SECTION 27. Any corporation or association, organized in this state under previously existing statutes, may, by a majority vote of its stockholders or members, be brought under the provisions of this act by limiting its membership and adopting the other restrictions as provided herein. It shall make out in duplicate a statement signed and sworn to by its directors to the effect that the corporation or association has, by a majority vote of the stockholders or members, decided to accept the benefits and be bound by the provisions of this act and has authorized all changes accordingly. Articles of incorporation shall be filed as required in section eight, except that they shall be signed by the members of the then board of directors. The filing fee shall be the same as for filing an amendment to articles of incorporation.

(a) Where any association may be incorporated under this act, all contracts heretofore made by or on behalf of some by the promoters thereof in anticipation of such associations becoming incorporated under the laws of this state, whether or not such contracts be made by or in the name of some corporation organized elsewhere, and when same would have been valid if entered into subsequent to the passage of this act are hereby validated as if made after the passage of this act.

Misdeameanor to Spread False Reports About the Finances or Management of Cooperative Associations

SECTION 28. Any person or persons or any corporation whose officers maliciously and knowingly spread false reports about the finances or management or activity of any cooperative association, shall be guilty of a misdemeanor and be subject to a fine of not less than one hundred dollars and not more than one thousand dollars for each such offense; and shall be liable to the association aggrieved in a civil action for damages therefor.

Warehousemen Liable for Damages for Encouraging or Permitting Delivery of Products in Violation of Marketing Agreements

SECTION 29. Any person, firm, or corporation conducting a warehouse within this state who silicits, persuades, or permits any member of any association organized hereunder to breach his marketing contract with the association by accepting or receiving such member's products for sale or for auction or for display for sale, contrary to the terms of any marketing agreement of which said person or any member of the said firm or any active officer or manager of the said corporation has knowledge or notice, shall be liable to the association aggrieved in a civil suit for damages therefor, courts of equity shall have jurisdiction to enjoin further breaches of such contracts.

Associations Are Not in Restraint of Trade

Section 30. No association organized hereunder and complying with the terms hereof shall be deemed to be a conspiracy or a combination in restraint of trade or an illegal monopoly; or an attempt to lessen competition or to fix prices arbitrarily nor shall the marketing contracts and agreements between the association and its members or any agreements authorized in this act be considered illegal as such or in unlawful restraint of trade or as part of a conspiracy or combination to accomplish an improper or illegal purpose.

Constitutionality

Section 31. If any section of this act shall be declared unconstitutional for any reason, the remainder of this act shall not be affected thereby.

Application of General Corporation Laws

Section 32. The provisions of the general corporation laws of this state and all powers and rights thereunder, shall apply to the associations organized hereunder, except where such provisions are in conflict with or inconsistent with the express provisions of this act.

Numerous modifications and changes in the foregoing Act have been recommended by the Codification Commission, some of which at least will likely be passed by the Legislature at its next session and become effective in due time. The Act as given herein, however, was in force at the time this bulletin was printed.

Secretary Hyde on Farm Relief

The following paragraphs are taken from an address by Arthur M. Hyde, Secretary of Agriculture, on July 4, 1929 just after the creation by Congress of the Farm Board, before the National Education Association at Atlanta, Georgia.

"One general answer to farm problems is organization—organization to control marketing, to standardize output, to eliminate the waste and duplication of a marketing and distributing system which, generally speaking, absorbs two dollars for every one dollar it returns to the farmer. Thus the farmer can approximate the position of industry, or of other groups, By the long arm of his organization, the farmer can make himself felt beyond his line fences and in the markets of the world. Through his organization, the farmer can get information as to commodity supplies, can bring his production within the limits of demand, can control the surplus problem by preventing it. By organization the farmer can take control of his own industry; reestablish the independence of his calling; win his own place in the sun of economic equality, and having won it, hold it against all the changing vicissitudes of the future.

"To assist in the organization of agriculture; to take the problems of the various farm commodities out of the realm of politics and partisan bickering, and to meet them in the realm of economics; to set up an authoritative tribunal which shall study each separate problem, and afford leadership for agriculture in all its phases; and to do this, not by subsidy nor by governmental dabbling in business, but by helping the farmer to help himself through his own organizations—this is the aim and purpose of the Farm Relief Bill.

"The board does not buy or sell. It has no right to engage in business. Its job is to foster the organization of agriculture, to finance farmer-owned and farmer-controlled cooperatives, which may buy, sell, process, or store farm commodities.

*"The board serves in exactly the same capacity as a supervising architect serves the builder of a skyscraper or a bridge. The builder must provide the necessary funds, and a proper plan. The supervising architect must find the answer to technical questions and see the job through. * * * * * * The plan is made; the funds provided; the board is ready to supervise the job.*

"Rome was not built in a day, nor will agriculture be emancipated over night. Much depends upon the character and ability of the men who compose the board. But much depends, too, upon the cooperative associations which are already formed, or will hereafter, be formed. The board can not function on its own account. The initiative lies with the farm cooperative associations.

"It is not an evasion of the responsibility, but a statement of fact to say that the success of the farm bill depends upon team work between the board and the farm cooperatives, in whose aid the legislation was designed and around whom it is built."

ULLETIN 222

March, 1929

VARIETIES OF Fruits for West Virginia

BY H. E. KNOWLTON

Agricultural Experiment Station
College of Agriculture, West Virginia University
F. D. Fromme, Director
Morgantown

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. .... President of the University
F. D. FROMME, Ph. D. .... Dean and Director
WALTER C. SCHNOPP, B. S. Agr. .... Agricultural Editor
JOHN C. JOHNSTON .... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D. — Agronomist and Geneticist
E. P. Deatrick, Ph. D. — Associate Agronomist (Soils)
W. H. Pierre, Ph. D. — Associate Agronomist
T. C. McIlvaine, Ph. D.† — Assistant Agronomist (Soils)
D. R. Dodd, M. S. — Assistant Agronomist
M. M. Hoover, M. S. — Junior Agronomist
H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc. — Animal Husbandman
Chas. V. Wilson, M. S. — Assistant Animal Husbandman
J. H. Longwell, M. A. — Assistant Animal Husbandman
J. H. Rietz, D. V. M. — Associate Veterinanrian
R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman

CHEMISTRY

R. B. Dustman, Ph. D. — Associate Chemist
Chas. E. Weakley, Jr., B. A. — Assistant Chemist
L. P. Hansen, Ph. D. — Assistant Chemist
T. B. Leith, B. A.** — Assistant Chemist
Leland Shriver, B. S. — Assistant in Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D. — Dairy Husbandman
L. M. Thurston, Ph. D. — Assistant Dairy Husbandman
K. S. Morrow, M. S. — Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡ — Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D. — Entomologist
W. E. Rumsey, B. S.** — State Entomologist
Edwin Gould, B. S. Agr. — Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D. — Farm Economist
F. D. Cornell, Jr., M. S. — Assistant Farm Mechanician
W. W. Armentrout, M. S. — Assistant Farm Economist

HOME ECONOMICS

Rachel H. Colwell, A. M. — Home Economist
Hazel C. Cameron, M. S. — Research Specialist in Foods
Nell Nesbitt, A. M. — Research Specialist in Home Mgt.

HORTICULTURE

H. E. Knowlton, Ph. D. — Associate Horticulturist
H. L. Crane, M. S. Agr. — Associate Horticulturist
K. C. Westover, M. S. Agr. — Assistant Horticulturist
M. B. Hoffman, M. S. — Assistant in Horticulture
W. N. McCubbin, M. A. — Assistant in Horticulture

PLANT PATHOLOGY

N. J. Giddings, Ph. D. — Plant Pathologist
Anthony Berg, M. S. — Associate Plant Pathologist
L. H. Leonian, Ph. D. — Associate Plant Pathologist
E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr. — Poultry Husbandman
T. B. Clark, B. S. Agr. — Assistant in Poultry Husbandry

*In cooperation with U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡Assigned to the Reymann Memorial Farms, Wardensville, W. Va.

Varieties of

Fruits for West Virginia

I. THE TREE FRUITS

IN the planning of new orchards, the proper selection of varieties should always be given careful consideration, for this often determines the success or failure of the venture. Many instances might be given of failures in the orchard business due to choosing varieties of poor quality or those ill-adapted to the purpose or to the locality.

Select Varieties That Are Adapted

The varieties adapted to the region and locality should be ascertained. For example, the McIntosh apple should not be planted in West Virginia, because when grown here it colors poorly, drops prematurely, and is only fair in quality. It thrives best in the Great Lakes Region and in New England. The Albemarle Pippin, though adapted to this general region, should be planted only in the Albemarle section of Virginia where soil and local climatic conditions are peculiarly suited to it. If possible, varieties of known adaptation should be considered first. Varieties untested in the general locality should not be planted extensively, particularly if they have a reputation for being sensitive to soil or climatic requirements.

Fewer Varieties Are Being Grown

Today there are fewer varieties from which to choose, so the problem of selection is not as difficult as it was twenty-five years ago when hundreds were being grown and hundreds described in pomological literature and in fruit catalogs. This trend toward fewer varieties is shown in the nursery catalogs. Thus, in a 1916 catalog of a leading nursery, 50 varieties of apple, 30 of peach, 16 of pear, 20 of cherry, and 27 of plum are listed, while in their 1927 catalog the same nursery lists, only 30 varieties of apple, 19 of peach, 15 of pear, 15 of cherry, and 19 of plum.

The gradual decrease in the number of varieties grown has come with commercialization of the fruit industry. Standardization of varieties, along with standardization of grades and packages, has been necessary for the economical production and selling of fruit. The

peach industry has concentrated on the variety Elberta, and the pear industry on the Bartlett and Kieffer. The state of Washington has reduced its number of varieties of apples, from more than a hundred, to six, viz., Winesap, Jonathan, Delicious, Spitzenburg, Rome, and Stayman. These six varieties now constitute 90 percent of the state's total shipments. Other states are following the example of Washington. As a result one finds today that twelve varieties represent nearly 80 percent of the commercial apple crop of the United States.

Consider Market Possibilities

The variety problem is somewhat different for the grower who sells on a local market, and needs a number of varieties which ripen in succession in order to provide a constant supply for his customers throughout the season. He might also profit, however, by growing standard varieties, and concentrating on those that are the most profitable to the car-lot grower. If this is done, he has the advantage of being able to sell on the general market, in case his local market is over supplied.

The varieties described in this bulletin are those that the writer has had under observation for a number of years. Leading fruit growers of the state have also given their opinions of certain varieties. There are probably others that should be given a place here, but until firsthand knowledge is obtained it seems best to omit them.

THE APPLE

THE apple, the most cosmopolitan of fruits, is well adapted to all sections of West Virginia. It does not seem wise, however, to recommend the extensive planting of apple trees where the market is a general one. The apple industry at the present time is suffering from over-production with prospects that the situation will become worse as producing orchards increase in fruitfulness and as new ones come into bearing. The far-seeing orchardist, therefore, will not plant more trees, but instead will abandon those in his orchard which have little possibility of returning a profit due to unfavorable conditions, such as a poor site, wrong varieties, and many missing trees, and give better care to those that he knows, from their past performance, are most likely to bring a profitable return.

Guard Against Over-Production

The conditions that exist where local marketing is possible are quite different. Undoubtedly, there is considerable room for expansion in the business of apple growing in many sections of the state,

particularly in those localities where there is extensive industrial development. Orchardists in such sections should study the local situation carefully, however, before planning the establishment of new orchards.

Varieties of Apples

VARIETIES of apples that are under test in the Experiment Station orchards at Morgantown include: Alexander,* Arkansas (Black Twig, Paragon),* Arkansas Black,* Bailey Sweet,* Baldwin,* Benoni, Ben Davis,* Bismark,* Black Ben, Champion, Chicago, Cortland, Delicious,* Domine,* Early Harvest,* Early Melon,* Ensee, Esopus,* Fall Pippin,* Fall Rambo,* Fameuse (Snow),* Gano,* Gallia Beauty (Red Rome), Golden Delicious,* Golden Gate,* Golden Winesap,* Grimes,* Hubbardston,* Jonathan,* King David,* Maiden Blush,* Mann,* McIntosh,* Mother,* Newtown (Albemarle Pippin) Northern Spy,* Northwestern Greening,* Oldenburg (Duchess),* Red Astrachan,* Rhode Island Greening,* Romanite,* Rome,* Smokehouse,* Stark,* Stayman,* Summer Rambo,* Sweet Bough, Tolman,* Tompkins King,* Transparent,* Twenty-Ounce,* Wagner,* Wealthy,* Westfield,* Williams,* Willow Twig, Winesap,* Winter Banana,* and York.* The varieties of crab apples under test are Hyslop,* Transcendent,* and Whitney.* Only the varieties that seem to be worthy of consideration in future plantings are described herein. They are considered in order of ripening, in so far as possible.

Transparent (Yellow Transparent)

THE Transparent variety is of Russian origin, being in an importation of varieties made in 1870 by the United States Department of Agriculture. It is adapted to a wide range of conditions and is grown successfully in almost every apple growing section of the United States. It is perhaps our earliest commercial variety.

The fruit is medium to small on slow growing mature trees, especially if they are overloaded. The skin is tender and smooth with a thin, whitish bloom;† color is pale greenish yellow becoming nearly white when mature. Flesh is white, fine-grained, tender at maturity but becomes mealy when overripe. Flavor is sprightly subacid,‡ more

*Varieties in bearing upon which a report can be made. Other varieties were not old enough to bear at the time this report was prepared.
†A delicate, white, somewhat powdery substance on the surface of the fruit.
‡A term that means slightly acid but not noticeably sour.

mild when fully mature. The variety is an excellent one for culinary purposes.

The trees bear at an early age—sometimes the second or third year after setting. Under good conditions crops are produced nearly every year. If overloading is permitted, a biennial bearing habit develops. With heavy production, thinning is generally necessary for size. Transparent is very susceptible to fire blight seemingly in all its forms. Blossom blight is very serious in some seasons.

Tranparent is an excellent variety for both the home and general market. One should be careful, however, not to overplant with it as the demand is limited. While it can be kept in cold storage for a few weeks it generally comes in competition with much better varieties when taken out.

Early Harvest

THIS variety, supposedly of American origin, has been in cultivation more than a hundred years. Nothing definite, however, is known of its origin.

The fruit is usually medium to below medium in size. Skin is thin, tender, smooth, pale waxen yellow, sometimes slightly blushed. Flesh is white, fine, crisp, juicy, briskly subacid at first but becoming milder as the fruit matures, excellent for culinary purposes and later, when mature, agreeable for dessert. The color is such that bruises show readily. Its season is about the same as that of Transparent.

The trees are medium in size, moderately vigorous, coming into bearing early, and yielding crops almost every year. The crop ripens unevenly which makes the variety undesirable for the general market.

Early Harvest has been planted to some extent in this state by growers catering to the local market where a dessert variety ripening with Transparent has been in demand.

Oldenburg (Duchess)

OLDENBURG is also a Russian variety, having been imported to England from Russia in 1815 and later brought to New England by the Massachusetts Horticultural Society. It has been disseminated in some sections under the name of "Duchess" or the full name of "Duchess of Oldenburg." In general, it is adapted to the same range of territory as Transparent. It is considered by some as the most valuable Russian variety in cultivation in the United States.

The fruit is medium to large and uniform in size and shape. Skin is fairly thick, tender and smooth; color is greenish-yellow, attractively splashed and striped with red. Flesh is tinged with yellow, fine, crisp, tender, and juicy. Flavor is very sprightly subacid. The variety is excellent for culinary purposes.

Oldenburg comes into bearing early and bears heavy biennial crops. The tree is vigorous while young but later becomes only a moderate grower. The fruit ripens unevenly, necessitating several pickings. Like Transparent it is very susceptible to fire blight. Thinning should be practised for both size and color. In the Station orchard it has not colored as well or attained the size that the writer has seen in the northern apple sections.

Oldenburg is an excellent variety to follow Transparent for the local market trade. As a commercial sort for the general market, it has not found much favor among West Virginia growers probably because of the invariably overloaded condition of the market each year during its season of ripening.

Williams (Williams Early Red)

ALTHOUGH Williams is an old variety, its good qualities have not been recognized until recent years. It was discovered growing wild on the farm of Captain Benjamin Williams of Roxbury, Massachusetts, more than 150 years ago.

Fruit is medium and under favorable conditions large in size. Skin is thick but not tough, smooth, light green covered with streaks and splashes of deep red. Flesh is greenish white sometimes tinged with red, firm, somewhat coarse and juicy at picking time, becoming more tender and eventually mealy when overripe. Flavor is a pleasant, mild, subacid one. Its firm flesh and fairly tough skin make it the best variety of its season for long shipment. It is most satisfactory for dessert.

The tree is a rather slow grower and does better when top worked on a vigorous stock. A strong point in its favor is the fact that its season of bloom is long, extending over into the season of late blooming varieties such as York and Rome. Fruit is very firm when ready to fall from the tree. Since it matures quite slowly after picking, it is exceptionally good for the early export market. It is comparatively free from fire blight. Some of its weak points are unevenness in ripening and a tendency to drop before fully colored.

Williams has been rather extensively planted in recent years by West Virginia growers and also by growers for the general market all the way from New Jersey to South Carolina. Of course, the crop over this wide area will not all be marketed at the same time, still it would appear that when all these new plantings come into maximum production, prices will not be as attractive as they have been in the past. It must be remembered that certain qualities of this variety mitigate against over-production—it is an excellent shipper and probably the best keeper of its season. Certainly the variety can safely be recommended for the local market trade.

Wealthy

RANKING with Transparent in its ability to thrive over a wide range of territory is the Wealthy, a seedling grown by Peter M. Gideon, of Excelsior, Minnesota. The American Pomological Society reports it as succeeding in twelve of the eighteen pomological districts of America.

The fruit is medium to large when properly grown but is likely to run small on old trees, particularly, if they are heavily laden. Skin is thin, tough, and yellowish green in color, blushed and marked with narrow stripes and splashes of red. Flesh is whitish, crisp, and juicy, with an agreeable sprightly subacid flavor. For culinary purposes it is one of the best varieties of its season (late summer). When mature it is a fairly good dessert apple.

The tree is moderately vigorous. It comes into bearing at an early age and generally produces annual crops, if not allowed to become overloaded. The variety is very susceptible to fire blight and cedar rust.

Wealthy has become quite a favorite with West Virginia growers for supplying both the local and general market. In recent years, however, the variety has not been profitable on the general market because of increased competition from other varieties and because the supply has generally been greater than the demand. It is, however, gaining in favor as an export variety, and still remains one of the popular varieties of its season for the local market.

Maiden Blush

MAIDEN BLUSH is one of the best known and one of the most popular varieties of its season. As early as 1817 the variety was in strong demand on the Philadelphia market and the best variety of its season for drying.

The fruit is medium in size, sometimes large, generally running very uniform in size and shape. Skin is thin, tough, pale waxen yellow with a bright pink blush. Flesh is white with a yellow tinge, fine, moderately crisp, tender, subacid. Its color is such that it shows bruises readily. Maiden Blush is particularly liked for culinary purposes as it cooks to a fine sauce.

The tree has an open habit of growth, is moderately vigorous, and comes into bearing rather young. It generally bears moderate annual crops. The tree is quite susceptible to fire blight, and to apple scab and apple blotch.

Maiden Blush has not become a popular commercial sort for the general market in this state. It is one of the best varieties of its season, however, for the local market and may be planted along with Wealthy for the late summer and early fall trade. The variety is not adapted for storage, as it loses quality rapidly after being picked.

Mother

THIS variety was described in 1848 as being "a new handsome late autumn and early winter apple of the highest quality." It originated at Bolton, Massachusetts. Although an excellent dessert apple, it is but little known in West Virginia.

The fruit is medium in size, sometimes large. Skin is rather thick and tough, waxy, golden yellow, nearly covered with bright deep red marbled and striped with carmine. Russet dots and a heavy scarf skin give it a rough appearance. Flesh is firm, rich, yellow, juicy, crisp, fine grained. Flavor is rich, aromatic, subacid, and satisfies the most fastidious. When not overripe it is excellent for all culinary purposes.

The tree is moderately vigorous, does not come into bearing young and commonly bears biennial crops. It is quite free from disease. It blooms late—nearly as late as Northern Spy and Rome Beauty.

While Mother cannot be recommended for the general market it should be more extensively planted for the home orchard and local market.

Northwestern (Northwestern Greening)

ORIGINATING in Waupaca County, Wisconsin, the Northwestern was introduced to the trade in 1872. Because of its hardiness it has been widely planted throughout the northern sections of the apple belt—Minnesota, Wisconsin, and adjoining states. It has been planted to some extent in West Virginia and neighboring states.

The fruit is large, with a thin, tough, smooth skin, pale yellowish green in color. Flesh is greenish white, firm, coarse, juicy, with a subacid flavor. It is rather poor in quality for dessert but cooks fairly well. It is especially desirable for baking because of its size and firmness.

The tree is large and vigorous and bears at an early age. Alternate light and very heavy annual crops are generally produced. The tree habitually forms narrow crotches with forks of equal size, being much worse than Delicious in this respect. Judicious pruning when the trees are young will help overcome this defect. The variety is especially susceptible to bitter rot and apple blotch.

There are quite a number of plantings of this variety in the Eastern Panhandle of West Virginia. In most years it has sold for attractive prices on the New York City market and in New England, because it is the earliest variety to ripen which is large enough for baking. The demand, however, is limited, consequently any marked increase in its planting would seem to be inadvisable at the present time.

Grimes (Grimes Golden)

FROM the consumers standpoint, Grimes is probably as popular as any variety now on the market, being excellent for both dessert and culinary purposes. The variety originated in Brooke County, West Virginia. Fruit from this tree was sold to New Orleans traders as long ago as 1804. It does best in the more southern apple districts. In the north it does not develop the best size, color, or quality.

The fruit runs medium to below medium in the average heavy crop. Skin is thin, rather tough, greenish yellow, generally becoming a deep yellow at maturity. Flesh is creamy yellow, firm, tender, crisp, juicy, with a rich, spicy, subacid flavor. Grimes generally keeps well in cold storage until midwinter. If the storage is too dry considerable shrivelling may occur. Grimes is also one of our most susceptible varieties to storage scald.

The tree is of moderately vigorous growth with stout, bushy branches which bear their crop without breaking. It commonly bears alternate heavy and medium crops. The fruit tends to run small on old trees, but by heavy pruning and by fertilization the size can be considerably increased.

Only one disease seems to be serious with Grimes. This is the so-called "collar rot" or "collar blight" which attacks the tree at the

base and kills it in several seasons. To eliminate this trouble nurserymen in recent years have been "double working" Grimes. While this has greatly lessened losses, it seemingly has not entirely eliminated the disease. Grimes also seems to be very susceptible to attack of the red bug.

At the time this bulletin was prepared Grimes ranked in importance among the first half dozen commercial varieties grown in West Virginia. Collar blight has been slowly reducing the number of trees, so a gradual decline in production of this variety may be expected.

Jonathan

THE first account of this variety was published in 1826. The original tree stood on the farm of Philip Rick, Ulster County, New York. It is supposed to be a seedling of Esopus Spitzenburg. It seems to find its best adaptability in regions other than that of its origin, reaching its greatest perfection in the valleys of the Ohio, Mississippi, and Missouri rivers. It has also been planted extensively in the Pacific Northwest.

Fruit is medium to rather small. Skin is thin, tough, smooth, and pale yellow, nearly covered with indistinct stripes and splashes of deep red, giving almost a blushed appearance. Flesh is yellowish often tinged with red, fine-grained, crisp, tender, juicy, with a sprightly, vinous, subacid flavor. This variety is excellent for both dessert and culinary purposes.

The tree is of moderate slender growth and comes into bearing early, producing nearly annual crops. The most serious weakness of the tree is its marked susceptibility to fire blight in all its forms. Another serious disease is the so-called "Jonathan spot" of the fruit, which seemingly is very hard to control. It is particularly serious when the fruit is allowed to remain on the tree too long. The variety is also very susceptible to powdery mildew, a disease which is difficult to control.

Jonathan, up to the time of this report has been one of the important commercial varieties in West Virginia. Because of serious losses from the two diseases previously mentioned, the variety is becoming less and less popular with the grower. Certainly in sections where these two diseases are very prevalent, the variety should not be planted either for the home or general market.

Delicious

THE Delicious was first brought to notice by Jesse Hiatt, of Peru, Iowa, in 1881. It was then a sprout about six years old which had come up from the roots of a Yellow Bellflower tree. It was commercially introduced in 1895 under the name "Delicious."

The fruit is medium to large and sometimes very large. Skin is thick, tough with a light yellow ground color, blushed, mottled with dull pink, and indistinctly streaked with crimson and darker red. The effect is very similar to Winesap in many specimens. Flesh is yellowish, firm, fine grained, juicy, becoming mealy from the core outward at maturity. Flavor is a mild subacid to almost sweet with a distinctive rich aroma. Specimens with poor color, however, are almost tasteless. The value of Delicious lies chiefly in its dessert qualities. However, there are many persons who do not like its perfumed richness. It is very unsatisfactory for culinary uses due to its lack of acidity.

The tree is vigorous and healthy, coming into bearing at a somewhat early age and producing moderate annual crops. Great care must be exercised in training and pruning the young tree because of its tendency to form narrow angle crotches with each fork of similar size. Such crotches are weak and generally split when the limbs later become heavily laden with fruit. The tree is quite resistant to blight, but susceptible to scab. It is an early bloomer, consequently it often suffers from severe frost injury.

Delicious has been heavily planted during the last ten years throughout the apple growing sections of the East and West. There is naturally a question in the minds of many regarding the permanency of the present attractive prices for this variety when all these trees reach maximum production. Delicious has been extensively advertised to the consumer which partially explains the heavy demand for it. Because of its characteristic shape it is easily recognized on the market. As a result of this, Delicious is probably better known by the customer than any other apple. Its failure as a culinary sort and the lack of quality in poorly colored specimens, of course, are serious drawbacks.

Starking

THE Starking apple appeared as a bud sport on a Delicious tree in the orchard of Lewis Mood, Monroeville, New Jersey, in 1922. Stark Brothers Nurseries introduced it in 1924.

Starking in every respect except color seems to be identical with Delicious. The apples color much earlier than Delicious and when mature are a solid red. This quality is a valuable one especially in localities where Delicious is likely to color slowly—in such sections Delicious is often left on the tree until overripe in order to get color. From all indications Starking will not have this fault.

Golden Delicious

GOLDEN DELICIOUS originated as a chance seedling in Clay County, West Virginia, on the farm of H. Mullens. It was brought to the attention of Stark Brothers Nurseries, who introduced it in 1916. It was given the Wilder Silver Medal by the American Pomological Society in 1920.

Fruit is medium to large. Skin is thin, tough, smooth, somewhat roughened by prominent raised russet dots, golden yellow in color, sometimes faintly blushed. Flesh is yellow, firm, crisp, but not tender, juicy, with a mild subacid flavor which resembles Grimes. It promises to be an excellent variety for both dessert and culinary purposes. Its storage limit is about the same as that of Stayman.

The tree is healthy and vigorous, comes into bearing early, and the young trees produce nearly annual crops. Final opinion on tree characters cannot be given, however, until the trees under observation are more mature.

Golden Delicious has been widely but not extensively planted in West Virginia. It promises to rival Grimes as the standard yellow winter variety because of its many points of superiority. It is larger, better in quality, and a longer keeper. It is also less subject to storage scald. Its tree characters, as far as can be judged from the young trees, are also decidedly better than those of Grimes. One of its chief faults is a lack of a smooth finish on the fruit due largely to its prominent russet dots. Golden Delicious shrivels in storage—particularly when picked in an immature condition, but if the golden yellow color is allowed to develop before picking little shriveling occurs.

Winter Banana

WHILE this variety originated on the farm of David Flory, Adamsboro, Indiana, about 1876, it was not introduced until 1890.

The fruit is fairly large to very large. Skin is smooth, moderately thick, tough, waxy, bright pale yellow with a beautiful pinkish red blush in most specimens. Flesh is yellowish, moderately firm, crisp,

tender, juicy, with a mild subacid, aromatic flavor. Winter Banana is highly esteemed for its dessert qualities by those who prefer a mild flavor, but has little value for culinary purposes. It keeps well until midwinter.

Trees are medium in size and of vigorous growth, coming into bearing early and yielding moderate to heavy annual crops. They seem to be somewhat immune to fire blight.

Winter Banana has been rather widely but not extensively planted in West Virginia. The fact that its color, like Maiden Blush, is such that it shows bruises readily, is one of its main defects. It is also likely to sunburn badly in the hot, sunshiny days of August and September. Undoubtedly, it is a good variety for the local market where there is a demand for a yellow apple. It is doubtful, however, if it can compete with the several attractive red dessert varieties of its season.

Stayman (Stayman Winesap)

THE Stayman originated from seed of a choice lot of Winesap grown in 1866 by Dr. J. Stayman of Leavenworth, Kansas. It first fruited in 1875. Its merits were not recognized until 1890 when two men, R. J. Black of Bremen, Ohio, and J. W. Kerr of Denton, Maryland, fruited the variety on top grafts.

This fruit is medium to large if trees are not too heavily loaded. Skin is rather thick, moderately tough, greenish yellow in color, often covered with a dull red indistinctly striped with dull carmine. The general effect is a light red. Flesh is yellowish, firm, tender and juicy, with a mild subacid flavor. Stayman is excellent for both dessert and culinary purposes. It keeps well until late winter.

The tree is vigorous with an open top and stout upright-divergent branches. It comes into bearing fairly early and yields moderate annual crops. Fire blight does not seem to attack it to any considerable extent. It is, however, susceptible to scab.

Stayman has been extensively planted in the Eastern Panhandle of West Virginia. These plantings are now beginning to produce heavily. Generally speaking, it is well liked by the growers. Its chief faults are lack of color in some seasons, a tendency to crack, and failure to set fruit in solid blocks due to self-sterility. It undoubtedly is one of the most promising of the newer varieties that have been planted in recent years, being a favorite on the general as well as on the local markets.

Rome (Rome Beauty)

ROME was originated by H. N. Gillett of Lawrence County, Ohio, and brought to the attention of the Ohio Convention of fruit growers in 1848. The original tree stood on the banks of the Ohio until 1860 when it was washed away by high water.

Fruit is medium to large. Skin is thick, tough, smooth, with a yellow ground color mottled and striped with bright red shading to a darker red. The flesh is somewhat coarse, firm, crisp, and moderately juicy until mature, when it quickly becomes dry and mealy. The flavor is a mild subacid one which becomes insipid when the apple becomes mealy. The variety is a good culinary one and is well liked for its dessert qualities until it becomes overripe. It stands rough handling well. Its commercial limit in storage is about March.

The tree is of vigorous growth tending to grow thick and bushy if not well pruned. It cannot be considered a very early bearer, but as soon as its bearing habit becomes established it produces nearly annual crops. Because of its habit of bearing good crops annually on terminals, it is one of our most fruitful and profitable varieties. Rome is probably the latest blooming commercial variety in this section and consequently its buds are seldom injured by frost. It is quite susceptible to fire blight, cedar rust, apple scab, and storage scald. The color is best on elevated land, low river bottom fruit often lacking color.

In the Ohio Valley section Rome is the leading commercial variety. It is a favorite because it is highly productive, adaptible to various soils and locations, makes an attractive appearance when placed on sale, and because it can be either barrel, basket, or box packed. This apple is well liked by the consuming public, especially in the industrial centers of Ohio and Pennsylvania where it finds its chief market. The variety seems to be better adapted to the Ohio Valley than to the Eastern Panhandle sections.

Bud sports of Rome have appeared in several sections of the country in which the color shows a higher development than in Rome. When well colored the fruit is a solid red without stripes or splashes. These sports, although they have a separate origin appear to be identical. One of them has been introduced as Gallia Beauty, still another as Red Rome. They seem to be the same as Rome in every character except that of color. Growers familiar with them say that they are superior to Rome.

York (York Imperial)

YORK takes its name from its place of origin on the farm of a Mr. Johnson, near York, Pennsylvania. Mr. Johnson's attention was brought to it by schoolboys visiting the tree in the early spring to get the apples that had been on the ground over winter covered with leaves. Mr. Jonathan Jessup began the propagation of it in 1830 under the name of Johnson's Fine Winter. It was known under this name for a time until the late Charles Downing after an inspection of specimens pronounced it to be imperial in its keeping quality and suggested the name York Imperial. It has been widely distributed through Maryland, Pennsylvania, and the Virginians, and has become one of the leading commercial varieties.

Fruit is medium to large when well grown. The skin is thin, tough, smooth, pale yellow, shaded and striped with bright pink to deep crimson. Flesh is yellowish, very firm, crisp, somewhat coarse, moderately juicy, with a pleasant but distinctive subacid flavor. The quality is excellent for sauce and pie as it retains its shape when cooked. It is considered one of the best for canning purposes. Its storage limit is slightly longer than that of Stayman. It is likely to scald badly in storage.

The tree is large, of dense, vigorous, bushy growth, comes into bearing moderately early, and yields heavy biennial crops. It seems also to be very long lived. By heavy pruning and fertilization it can be made to bear annually, but fruit is generally oversized and poor in color. Thinning is generally needed as the fruit tends to set in clusters. If thinning is not done the apples are likely to be uneven in size with many undersized, poorly colored fruits. Because of the bushy habit of growth of the tree much pruning is required to get size and color. It is moderately susceptible to fire blight. Cedar rust attacks it rather badly. It blooms late, consequently it is seldom caught by frosts.

York is probably the most important commercial variety in West Virginia. There is much dissatisfaction with it, however, as evidenced by the fact that few trees of this variety can be found in the younger plantings. Because of the immense size to which the trees grow the variety will produce in the crop year a heavier tonnage per acre than any other variety grown in this section. York will stand rough handling better than most varieties, sells well on the export market, and is a favorite variety with the canners. Its mediocre quality is against it,

however, especially when it comes into competition with varieties of higher quality such as Grimes and Stayman.

Arkansas (Mammoth Black Twig)

THIS variety originated near Rhea Mills, Arkansas, from seed planted about 1833. It is probably a seedling of Winesap which it markedly resembles. Nurserymen began the propagation of it about 1868. Arkansas is its correct name and the one officially adopted by the American Pomological Society. It is known to the grower and to the trade by the name "Black Twig." Another variety, Paragon, also a seedling of Winesap, has been confused with Arkansas. Paragon originated in Tennessee. The fruits of the two varieties so closely resemble each other that they seem almost identical. Some growers claim that Paragon is more productive than Black Twig.

Fruit of Black Twig is medium to large. Skin is thick, tough, becoming more or less oily in storage, with a dull yellowish green ground color overlaid with a dull light red shading to a darker red. Flesh is a greenish yellow, firm, crisp, somewhat coarse, moderately juicy, with a rich subacid flavor. It is excellent for both dessert and culinary purposes. The quality is not as high as either Stayman or Winesap. It scalds badly in storage. At picking time this variety is very hard and will stand considerable handling without being seriously injured. It ranks about with Winesap in keeping quality.

The tree is large, healthy, and vigorous with strong, stocky branches. Its bearing habit is variable. Trees in the Station orchards have borne moderate crops their ninth and tenth year. In other localities growers have reported a marked tardiness in coming into bearing. The fruitfulness of mature trees also differs widely, some growers reporting good productivity, others a lack of it. The majority of all reports, however, would indicate that the variety is a shy bearer in West Virginia. Arkansas is self-sterile. Undoubtedly, many of the cases of low yields are due to a lack of proper cross-pollination.

Arkansas is a variety that has so many good qualities in both tree and fruit that one hesitates to discard it, but because of lack of productivity it is likely to disappear eventually.

Winesap

NOT much is known as to the origin of this variety. Coxe, in 1817, mentions it as being "the most favored cider fruit in New Jersey." From this fact many writers have thought that to be the probable place of its origin.

The fruit is medium to small, rarely large. Skin is moderately thick, tough, smooth, glossy, yellowish green, blotched and indistinctly striped with crimson, deep carmine and purple. Flesh yellowish, firm, juicy, moderately coarse with a rich, sprightly subacid flavor. Winesap is an excellent dessert variety and excels also for culinary purposes.

The tree is smaller and not of as vigorous a growth as Stayman nor are the branches as stout and the leaves as large. Like Stayman, Winesap is generally free from attacks of fire blight, but is quite susceptible to apple scab.

Winesap, undoubtedly, ranks among the first half dozen varieties in West Virginia as judged by number of trees. It is very particular, however, as to soil and elevation, lacking color at low, and size at high, elevations and on poor soils. It generally colors better than Stayman. Many growers do not like it because of its low yielding ability—mainly due to small trees and small fruit. It probably is as completely self-sterile as any of the standard varieties of apple, consequently it must be planted adjacent to other varieties. Winesap keeps well, retaining its maximum quality in cold storage until almost midsummer. In the localities where it is adapted it is unexcelled for both the general and home market.

Varieties of Crab Apples

Transcendent

THE origin of Transcendent crab apple is unknown. The Prince Nurseries listed it in their catalog as early as 1844.

Fruit is medium to large. Skin is thin, clear bright yellow in color, blushed and splashed with bright red and overspread with bloom. It ripens in late August and September.

Tree is large, vigorous, comes into bearing early, and is a good producer. In the Station orchard it has been very susceptible to fire blight. It blooms early and consequently blossoms are often severely injured by frosts.

Because of its beautiful color and high quality Transcendent can be recommended where an early variety is desired. It ripens a little too early, however, for either the home or general market.

Hyslop

HYSLOP is one of our oldest and best known varieties of crab apples, but its origin is unknown.

Fruit is above medium to large. Skin is pale yellow overspread with a dark red blush and with a thick bloom. Exposed fruits when fully mature are colored a solid dark red. Flesh is firm, fine grained, and juicy but becomes dry and mealy when stored. It ripens in late September.

The tree is vigorous, upright growing, begins to bear early, and seems to be a regular bearer. Its blooming period is later than that of Transcendent and it is not so susceptible to fire blight as is the earlier variety.

Hyslop is one of the most desirable varieties of its season for both the home and general market. Due to its lateness in ripening there is generally a greater demand for it than for Transcendent.

THE PEACH

THE peach is the second tree-fruit crop in point of importance in West Virginia. Plantings are widely scattered, the large commercial plantings being east of the Alleghenies, in Hampshire, Mineral, Morgan, and Berkeley counties, with the small orchards catering to local market demands being found west of the mountains.

The total number of bearing and non-bearing trees has decreased considerably in the last decade, most of the decrease being in the Eastern Panhandle. There are many reasons for the decline. Many peach trees had been set as fillers in the apple orchard, and as they began to crowd the apple trees they were removed. Lack of care and the ravages of the yellows disease and the peach-tree borer have all taken their toll. Low prices in some years, generally due to variation in time of ripening, bringing our peaches into direct competition with neighboring high producing sections, have made the future look discouraging to anyone considering the making of new plantings in the Eastern Panhandle. Thus, in 1926, due to the generally late season, West Virginia peaches went onto the market in direct competition with New Jersey and Delaware peaches. This resulted in extremely low prices. Normally, West Virginia peaches should precede by a few days those of New Jersey and Delaware.

Generally speaking, there seems to be room for expansion in the peach industry in the counties west of the Alleghenies. Here, there is a strong local demand, particularly near centers of industrial development—a demand that rarely is fully supplied by the few scattered small orchards. Local conditions as regards variety adaptability and market demands should be thoroughly studied before new plantings in this section are decided upon.

Varieties of Peaches

VARIETIES of peaches which are under observation in the Experiment Station orchard at Morgantown are: Alton, Apex,* Artic,* Banner, Belle,* Bilmeyer,* Bray's Rareripe,* Brunner's Favorite,* Burton,* Buttercup, Carman,* Chair's Choice, Champion,* Crawford Late,* Crosby, Cumberland, Day's Nonpariel,* Delicious, Dewey, Early Elberta,* Early Mamie Ross, Easton Cling,* Eclipse, Elberta,* Engles Mammoth, Fox Seedling,* Frank,* Gibson Cling, Greensboro,* J. H. Hale,* Heidelberg,* Hiley,* Japan Blood,* Kalamazoo, Krummel,* Martha Free, Marigold, Massaoit, Mayflower,* Meteor, Niagara, Oriole, Pioneer, Primrose, Radiance, Reeves,* Rochester,* Rosebud, Salwey,* Shippers Late Red, South Haven, Smock, Sunbeam, and Waddell.*

Mayflower

NOTHING is known as to the origin of this variety except that it is said to have originated in North Carolina.

Fruit is medium sized and oval in shape. Skin is heavily pubescent (fuzzy), creamy white with a dark red blush. Flesh is greenish white, juicy, tender, subacid in flavor and clings to the rather large stone. It is only fair in quality and is not a good shipper. Mayflower is the earliest peach in the Experiment Station Orchard, ripening about the middle of June.

Tree is large, vigorous, open, hardy, and productive. It is one of our hardiest varieties in the bud.

Mayflower is an important commercial variety in the South, being grown there chiefly because of its extereme earliness. It undoubtedly would be a profitable variety to plant in a very limited way for local markets in West Virginia.

*Varieties in bearing upon which a report can be made. Other varieties were not old enough to bear at the time this report was prepared.

Greensboro

THIS variety is a seedling of Connett which was grown at Greensboro, North Carolina, about 1891. It was placed on the list of recommended varieties by the American Pomological Society in 1899.

Fruit is medium to large and oblong-oval shape. Skin is tough, creamy white in color, blushed and striped with light and dark red. Pubescence is heavy. Flesh is white, juicy, tender, sprightly, fair in quality, half clinging to the stone. The fruit stands shipping well.

Tree is large, vigorous, spreading, open, hardy, and productive. It is even more hardy in the bud than Mayflower.

Greensboro is one of the best early, white-fleshed peaches, ripening in the Experiment Station orchard about July first. Because of its excellent tree characteristics and the high resistance of its fruit buds to low temperatures, it has been our most reliable cropper at Morgantown. While planting of this variety in a limited way for the local market can be recommended, it cannot be for the general market. It is a white clingstone of mediocre quality. The trade will not buy such a peach when it can get varieties of better quality ripening at the same time from the South.

Carman

THE Carman variety was originated by J. W. Stubenrauch, of Mexia, Texas, in 1889. Its many good qualities so pleased Mr. Stubenrauch that he named it Pride of Texas and began propagating it in 1892. The name later was changed to Carman in honor of the late E. S. Carman, editor for many years of the Rural New Yorker.

Fruit is medium in size and round-oval in shape. Skin is thin, tough, creamy white in color, more or less covered with light red with splashes of darker red. Pubescence is very thick and short. Flesh is white, juicy, and sweet, with a mild pleasant flavor. Stone is almost free. Carman is above the average in quality for a variety of its season. It ripens the latter part of July in the Experiment Station orchard at Morgantown.

The tree is large, vigorous, spreading, hardy in both wood and bud, and very productive.

Carman is one of the best varieties of its season for the home or local market. Like Greensboro, on the general market it generally comes into competition with better quality yellow peaches from the South, particularly Elberta.

Rochester

ROCHESTER came from a seed planted about 1900 on a farm owned by a Mr. Wallen, near Rochester, New York. It was introduced in 1912 by the Heberle Brothers Nurseries of Brighton, New York.

Fruit is medium to large in size, and round-oblate in shape. Skin is thick, tough, lemon yellow changing to orange yellow in color, blushed and mottled with dark red. Flesh is yellow, streaked with red near the pit, juicy, tender, sweet, and highly flavored. Stone is free. Pubescence is very heavy. It ripens the latter part of July.

Tree is large, vigorous, upright-spreading, hardy, and productive. Yellow peach varieties are considered to be more tender in the bud than white ones. Rochester ranks as one of the hardiest of the yellow peaches as measured by resistance to cold.

Rochester is one of the few new varieties that is promising. It has, however, several faults. Its pubescence is so heavy that it detracts a great deal from its appearance. It ripens unevenly, a quality that is good for the local but not for the general market. It seems, however, to be our earliest yellow peach of good quality. It is one of the few varieties that can be recommended for the local market.

Hiley

EUGENE HILEY, Marshallville, Georgia, originated this variety about 1886. It was a seedling that came from a collection of seeds of a number of varieties including Belle and Elberta. It was believed to be a seedling of Belle crossed with Alexander. It was first named Early Belle but later the name was changed to Hiley.

Fruit is medium to above medium in size and roundish-conic to oblong-conic in shape. Skin is thin, tough, greenish yellow with a dull red blush on one side, more or less mottled. Flesh is creamy white, stringy, tender, firm, with a pleasant agreeable flavor. Quality is good. Stone is semi-free to free. The variety ripens early in August.

Tree is medium in size, moderately vigorous, upright spreading, productive. It ranks with Belle in bud hardiness.

Hiley is undoubtedly a good variety to plant in a limited way for the home market. It has not been a profitable variety for the general market in recent years because it comes on the market when it is still well supplied with southern Elbertas.

Belle (of Georgia)

BELLE grew from a seed of Chinese Cling planted in 1870 by L. A. Rumph, Marshallville, Georgia. The other parent is believed to have been Oldmixon Free. The American Pomological Society first recommended it in 1899 under the name Georgia, but later changed the name to Belle. Popularly it is still designated "Belle of Georgia."

The fruit is medium in size and roundish-oval in shape. Skin is thin, tender, greenish white to creamy white in color, blushed and mottled with light and dark red. Flesh is white, tinged with red at the pit, juicy, stringy, tender, sweet and mild. Stone is semi-free to free. Quality is good. Pubescence is short, fine and rather thick. Belle ripens about the middle of August—a week or ten days before Elberta.

Tree is large, vigorous, spreading, open, hardy, and very productive. In the Experiment Station orchards Belle is not as hardy in the bud as Greensboro or Carman. Generally, however, a sufficient number of buds come through the winter to insure a heavy crop.

Belle is one of the best varieties of its season, but it is white-fleshed and whenever it ripens at a time that brings it in competition with the Elberta crop from more southerly sections it does not sell well. Because of this, commercial growers have found that profits from this variety have been very uncertain. It is a good variety for the home markets, however, because these usually do not have as heavy competition from other producing sections as do the markets of large cities.

Elberta

LIKE Belle, Elberta grew from a seed of Chinese Cling planted in 1870 by Samuel H. Rump of Marshallville, Georgia. The Chinese Cling tree from which the seed came, grew near Early and Late Crawford, Oldmixon Free, and Oldmixon Cling trees. Mr. Rump believed that the Early Crawford was the male or pollen parent. The seedling was named Elberta in honor of his wife, Clara Elberta Rump. Elberta has been widely and extensively planted in all peach sections of the United States. It is unquestionably the leading variety as judged by number of trees, productivity, and popular demand in the markets.

Fruit is medium to large in size, roundish-oblong in shape. Skin is thick, tough, deep yellow in color, partly overspread with red and

with much mottling over nearly the whole surface. Pubescence is thick and coarse. Flesh is yellow, juicy, stringy, firm yet tender, sweet or subacid, mild in flavor. Stone is free. Quality is fair to good. It ripens the last of August slightly ahead of J. H. Hale. It is a good shipper and keeper.

The tree is large, healthy, upright-spreading, vigorous, and productive. It is not hardy in the bud as grown in the Experiment Station orchards at Morgantown.

As Hedrick expresses it (Peaches of New York), "Elberta is the cosmopolite of cultivated peaches." Its chief fault under West Virginia conditions is a lack of bud hardiness. The defect manifests itself to a greater degree west of the Alleghenies where it seemingly is not a profitable variety except on very favorable sites. It can safely be recommended, however, as a profitable variety to grow in the commercial fruit districts of the Eastern Panhandle.

Various strains of Elberta have been introduced by nurserymen which are claimed to be superior to the old variety, some of them ripening earlier and some later. Only one has been tested at this Station, an Early Elberta. This strain ripens three or four days earlier than the old variety. The fruits seem to be identical with those of Elberta, but the trees do not grow as vigorously.

J. H. Hale

THIS variety is a chance seedling found by J. H. Hale, South Glastonbury, Connecticut. Probably Elberta is one of its parents. After extensive testing in orchards in Connecticut and Georgia, the new variety was thought worthy of introduction and was sold to the William P. Stark Nurseries of Stark City, Missouri. Advertising and distribution of the variety began in 1912. In the fifteen years that have passed since its introduction it has been extensively planted in all the important peach producing districts of the United States.

Fruit is medium to large in size and nearly spherical in shape. Skin is thick, tough, pale yellow in color covered with mottlings and splashes of attractive light and dark red. Pubescence is light. Flesh is yellow, juicy, fine-grained, and of good quality. Stone is free. It ripens the last of August at about the same time as Elberta or slightly later.

Tree is vigorous, somewhat stubby in its habit of growth, and productive. Trees, as a rule, do not grow as large as those of Elberta. Fruit buds of J. H. Hale are not very resistant to low temperatures, being more tender even than Elberta.

J. H. Hale seems to be a worthy rival of Elberta. Since it ripens at about the same time and must compete with it on the markets, a comparison of the two varieties will be made. Generally speaking, Elberta will be more productiee than J. H. Hale because its trees are larger and its fruit buds are more resistant to low winter temperatures. On the other hand, J. H. Hale peaches will run larger in size and will be more attractive than those of Elberta. The quality being also better they generally will sell at a somewhat higher price on markets where they are known.

J. H. Hale as grown in most sections of the East is self sterile—a definciency rarely found in the peach. Sterility in this case is due to the failure of the pollen to develop normally. The variety must, therefore, be interplanted with other varieties and provision made for cross-pollination by means of bees. When such facilities are provided, J. H. Hale will set heavily and may require some thinning.

J. H. Hale can be recommended for planting both for the local and general market in sections where the Elberta has proved itself to be a profitable variety. Unfortunately a very high percentage of the fruit buds of both of these varieties are annually winter killed in the Experiment Station orchards—so many as to reduce the yield materially. Observations in other sections west of the Alleghenies show a similar condition each year—an extremely high mortality among fruit buds of J. H. Hale and Elberta. A few orchards of these varieties in these sections, due to being placed on exteremely favorable sites, are bearing good crops. This difference in mortality of fruit buds east and west of the Alleghenies is due to different winter weather conditions.* Fruit growers in central and western West Virginia should study their local situation carefully, therefore, before planting J. H. Hale or Elberta.

Salwey

SALWEY is one of the few important varieties that are of European origin. Its history is obscure. One account gives Thomas Rivers, Sawbridgeworth, England, the credit for originating and introducing

*Consult: Knowlton, H. E. and Dorsey, M. J., "A Study of the Hardiness of the Fruit Buds of the Peach," W. Va. Agr. Expt. Sta. Bul. 211, 1927.

it. Another account says it was raised in 1844 by Colonel Salwey, Surrey, England, from the seed of an Italian peach. Few varieties are more widely grown, it being a standard variety in Europe as well as in peach sections of the United States.

Fruit is medium in size and round-cordate* in shape. Skin is thin, tough, greenish-yellow in color with a brownish-red blush, splashed dark red. Flesh is a deep yellow, juicy, stringy, tender, with a sweet, pleasant flavor. Quality is good, particularly for canning, preserving, and evaporating. Fruit ripens the latter part of September.

Tree is medium to large, vigorous, hardy, and productive. Buds are quite hardy for a yellow peach—generally enough survive the winter to insure a crop.

Salwey is an excellent variety for the local market to lengthen the season. As a commercial variety for the general market it is not large enough and attractive enough to compete with Elberta from the northern peach districts.

Krummel

KRUMMEL was originated by a Mr. Krummel of St. Louis, Missouri, some time previous to 1900. It is a well known variety in southern peach regions. It is not grown in the North because it ripens too late and would often be caught by late fall freezes.

Fruit is large in size, spherical in shape. Color is a light lemon yellow, very faintly blushed with carmine. Flesh is yellow, fine in texture, juicy, melting, good in quality. Stone is free. It ripens a little later than Salwey.

Tree is large, vigorous, hardy, fairly productive. It ranks with Salwey in fruit bud hardiness.

Krummel is undoubtedly a good variety for the local market where a very late variety is desired.

---

*The word "cordate" means heart-shaped.

THE CHERRY

CULTIVATED varieties of cherries belong to two species, Prunus avium, the sweet cherry, and Prunus cerasus, the sour cherry. The Dukes, the most important variety being May Duke, are crosses or hybrids between the two above mentioned species.

Sweet cherries lack adaptability to both soil and climate, consequently they thrive in but few regions, the Pacific Coast and the Great Lakes districts being the most important. Probably the chief drawback to their extensive culture in West Virginia is their lack of winter hardiness in both wood and bud. Warm spells, so characteristic of our West Virginia winters, cause the buds to swell and consequent sudden drops in temperature do great damage to wood and to fruit buds. Chandler says, "the wood of the sweet cherry is slightly more resistant to freezing than that of the peach, a few varieties such as Lyons and Wood being considerably more resistant. The tree, however, does not have as great ability as the peach tree to recover from the killing of a large part of the sapwood; and so, following some freezes, a larger percentage of sweet cherry trees than of peach trees are lost; though this is not generally true." Considerable injury to the wood has occurred in the variety orchard at Morgantown during several winters, one entire block of Schmidt being so badly injured that it had to be removed.

The sour cherry is one of our most cosmopolitan of fruits, often thriving with very little care. On the other hand, it will repay good culture as well as any of our fruits. All varieties are quite resistant to low temperatures both in wood and bud. Due to this fact their limited culture in West Virginia should be encouraged wherever there are markets to be supplied.

The Dukes, hybrids between the sweet and sour cherries, have some of the characteristics of both. Their culture in home orchards is recommended wherever a wide variety is desired. Uneveness in ripening, however, of many of the varieties make them poor for commercial markets.

Varieties of Sweet Cherries

THE following varieties of sweet cherries are under test in the variety orchards at Morgantown: Bing, Black Tartarian, Governor Wood, Ida, Lambert, Mercer, Napoleon, Schmidt, Windsor, and Yellow Spanish. Of these varieties, Ida, Wood, Tartarian, Napoleon,

and Windsor have done best. Yellow Spanish and Lambert are high in quality but lack hardiness. Mercer is hardy but the quality is poor.

Ida

IDA was first grown as a seedling by E. H. Cochlin of Shepherdstown, Pennsylvania, and named after his daughter. The fruit ripens about the first week in June. It is hardy in the bud, and consequently bears large crops. Fruit is soft fleshed, yellowish red in color, of good size, but mediocre in quality. The trees are healthy and vigorous. It can be recommended for trial in the home orchard because of its hardiness and productivity.

Wood (Governor Wood)

WOOD is a seedling raised by Professor J. P. Kirtland, of Cleveland, in 1842. It was named in honor of Reuben Wood, at one time Governor of Ohio.

The fruit ripens early, generally about the first week in June in the latitude of Morgantown. Trees are hardy and vigorous. The fruit is of good size and excellent quality, yellowish white in color, tinged with crimson. The flesh is soft, however, so it will not stand shipment. It is a good, early variety for the home orchard.

Tartarian (Black Tartarian)

THIS variety came originally from Russia. It was introduced into America by William Prince, of Flushing, New York, early in the nineteenth century. Probably no cherry variety is better known than Tartarian, it being grown over all Eastern United States. It is adapted to widely different soils and climates, is fruitful and hardy, and has excellent fruit characters that make it a general favorite.

Tartarian ripens with Ida. The fruit is glossy black in color with handsome purplish red flesh of a sweet, rich flavor. Its comparatively small size is a drawback for the commercial planter, as well as is its soft flesh. It is one of the best, however, for the home orchard.

Napoleon

NAPOLEON is a very old variety of unknown origin. It was grown over all Eastern Europe early in the eighteenth century. It was introduced into America in the early quarter of the nineteenth century.

On the Pacific Coast it is extensively grown and sold under the name Royal Ann.

Napoleon ripens about the second week in June. It is a large, firm fleshed cherry, reddish yellow in color, of the best quality, admirably adapted for dessert purposes as well as for canning. The cherries carry well, which makes the variety a favorite with fruit dealers. The tree is vigorous, hardy, and healthy.

Windsor

THIS variety originated in the latter half of the nineteenth century on the farm of James Dougall, of Windsor, Canada.

The fruit ripens late, generally about the third week in June in the latitude of Morgantown. It is medium sized, dark red in color, firm fleshed, and of good quality. The tree is hardy and vigorous but comes into bearing late. It is probably the most widely grown of the late sweet cherries.

Varieties of Sour Cherries

EARLY Richmond, English Morello, Duchess, Dyehouse, Marguerite, and Montmorency are the varieties that have been under trial in the Experiment Station orchards at Morgantown. Of these, Dyehouse, Early Richmond, English Morello, and Montmorency can be recommended for trial in West Virginia.

Dyehouse

THIS cherry was probably grown from a pit more than sixty years ago by a Mr. Dyehouse, of Lincoln County, Kentucky.

The fruit strongly resembles Early Richmond but is smaller and four or five days earlier. Due to its defect in size it is not as popular as Early Richmond. It is also less productive, and should be grown for home and market only wherever an earlier variety than Richmond is desired.

Richmond (Early Richmond)

EARLY RICHMOND is one of the oldest cherry varieties, being known in England as Kentish. It was brought to America early in the nineteenth century and was called Early Richmond because William Prince obtained his first trees of the variety from Richmond, Virginia.

The fruit ripens with the earliest of the sweet cherries. It is medium in size, light red in color, and fair in quality. The tree is hardy, vigorous, and fruitful. It is the best sour cherry of its season.

English Morello

THIS variety probably originated in either Holland or Germany. It was taken to England and France.

The fruit is medium in size, dark red in color with a soft, dark red flesh which is acid and often astringent until thoroughly ripe. It is probably the best of the sour cherries for preserving. While the trees are hardy and vigorous they never grow large and consequently should be set closer than Richmond or Montmorency. It ripens four or five days after Montmorency.

Montmorency

THE Montmorency was introduced into America very early, the exact date not being known. Its origin is obscure, but probably occurred in France. It has been confused with other varieties, particularly Richmond.

Montmorency is unquestionably the most popular sour cherry grown in America. Hedrick says that half the cherry trees in New York, sweet or sour, are Montmorencies and at least three-fourths of all sour cherry trees are of this variety. The fruit is larger than Richmond, of better quality, firmer fleshed, and thicker skinned. It ripens the last week in June.

Varieties of the Duke Group

THREE Duke (crosses between the sweet and cour cherry) varieties have been under test in the Experiment Station orchards at Morgantown. They are May Duke, Abbesse d' Oignies, and Royal Duke. All three are worthy of trial in the home orchard.

May Duke

T is believed that this variety originated in a district in France known as Medoc. Wm. Prince mentions it as being one of the first cherries introduced into America. It is now one of the best known and widely distributed varieties of cherries.

The fruit ripens with the earliest of the cherries. It is of moderate size, dark red in color with a soft, medium to dark red flesh and subacid but pleasant flavor. Tree is hardy, vigorous, and fruitful.

Abbesse d' Oignies

ACCORDING to Hedrick, of the New York Agricultural Experiment Station, this variety has so far been tried commercially only in the Middle West. At the New York Station it is one of the best of the Dukes. It is believed to have originated in Belgium about the middle of the nineteenth century.

The fruit ripens about the middle of June in the latitude of Morgantown. The tree is vigorous and hardy, and bears good crops of large, dark red cherries of excellent quality—probably of better quality than most of the varieties of Dukes. It also has their fault of tending to ripen unevenly.

Royal Duke

THE origin of this variety is not known, but it was in cultivation in Europe at least as early as the latter half of the eighteenth century.

The Royal Duke variety is an excellent one to follow May Duke, which it closely resembles. It differs from it in ripening a few days later; the cherries are larger and lighter red in color. The tree is vigorous, hardy and fruitful.

THE PEAR

THE production of pears in West Virginia should be limited to the small orchard supplying a local trade. A few commercial orchards have been planted in the past, but they have not been successful. Probably the prevalence of fire blight has been the chief cause of failure, spring and summer weather conditions being particularly favorable for the rapid spread of this disease.

Varieties of Pears

IN a limited way, the West Virginia Agricultural Experiment Station has been carrying on variety tests with pears. The following varities are under observation: Beurre' d' Anjou, Duchesse d' Angouleme, Bartlett,* Becurre' Bosc, Beurre' Clairgeau, Clapp's Favorite,

Doyenne' du Comice, Flemish Beauty, Garber, Howell, Keiffer,* King Karl, Koonce, Lawrence, Lincoln, Seckel,* Sheldon, Vermont Beauty, Wilder, and Winter Nelis.*

Bartlett

BARTLETT is an old English variety. It was brought to this country about 1797 by James Carter of Boston for Thomas Brewer of Roxbury, Massachusetts, under the name of Williams' Bon Cretien, by which name it was then and still is known both in England and France. In 1817 Enoch Bartlett got possession of the Brewer estate and not knowing the true name of the variety gave it the name Bartlett.

Fruit is medium to large with a clear yellow color, generally with a faint blush. Skin is thin, tender, smooth, sometimes slightly russetted. Flesh is fine grained, melting, buttery, very juicy and good in quality. It keeps and ships very well. It ripens late in August.

Tree is medium in size, upright, hardy, comes into bearing early, and is very productive. It is very susceptible to fire blight, however.

Bartlett is unquestionably the best commercial variety in the United States. Its great adaptability to different climates, soils and situations help to make it so. It is a variety that can be recommended for planting in a limited way for the home market.

Seckel

SECKEL originated as a chance seedling on a tract of land south of Philadelphia near the Delaware River. The land finally came into possession of a Mr. Seckel, who gave the pear his name and introduced it. It soon was widely disseminated and everywhere became popular. Next to Bartlett and Kieffer, it is now more grown than any other variety.

Fruit is small, uniform in size and shape. Skin is smooth, dull, of a greenish yellow color generally overlaid with a russet brown, sometimes with a russet red blush. Flesh is white tinged with yellow, melting, tender, buttery, juicy, with a rich spicy flavor. The quality is excellent. Fruit ripens in September.

Tree is large, vigorous, upright-spreading, bushy, hardy, long lived, very productive, but late in coming into bearing. It is remarkably free from fire blight, but susceptible to scab.

*Varieties in bearing upon which a report can be made. Other varieties were not old enough to bear at the time this report was prepared.

correct according to the rule of priority. Bradshaw is now one of the leading varieties in the Eastern States.

The fruit is medium to large and oval in shape. Skin is thin, somewhat tough, and of a dark, reddish-purple color overspread with a thick bloom.* Flesh is dull yellow, juicy, fibrous, tender, sweet, pleasant, good in quality. Stone is semi-free. It ripens early in August, is a good keeper, and ships well. It is very subject to brown rot.

The tree is large, vigorous, somewhat bushy, hardy, and productive. It is late in coming into bearing.

Bradshaw seems to be worthy of trial in West Virginia because of its good tree characters and large, attractive fruits.

Reine Claude (Green Gage)

REINE CLAUDE is the principal variety of a group of plums known as the Reine Claude group. Where it originated no one knows. The group has been recognized and described by pomological writers for three centuries. Its later history is better known. It was named after Queen Claudia, wife of Francis I of France, the fruit having been introduced into that country during their reign. The name Green Gage comes from the fact that it was introduced into England by the Gage family, prominent English horticulturists. Because of its great popularity it was brought to America by the early colonists. Reine Claude, the principal variety of the group, is one of the standard Green Gages grown in America.

Fruit is medium in size, roundish-oval in shape. Skin is tough, yellowish green, becoming a golden yellow at full maturity, overspread with a thin bloom. The exposed side is often mottled with red. Flesh is greenish yellow to golden-yellow, juicy, firm, sweet, mild, and of the highest quality. Stone is semi-clinging. Fruit often cracks badly if rain occurs at ripening time. It ripens late in August.

Tree is of medium size and vigor, round-topped, hardy, and productive, but seems to be quite susceptible to sun-scald.

Reine Claude is a good variety for the local trade because of its high quality and productiveness.

*A delicate, white, somewhat powdery substance on the surface of the fruit.

Tree is medium in size and vigorous, spreading, hardy, productive, coming into bearing early. It is quite free from blight.

Winter Nelis is a variety that can safely be recommended for the home market. While the fruit is not attractive in appearance it makes up for it in high quality and generally sells for good prices.

THE PLUM

THE PLUM, like the pear, should only be planted in West Virginia by the grower catering to local market demands. Since West Virginia is near the southern limit of range for the growing of the European plum there is a question as to whether it thrives well enough here to make it possible for us to compete with the northern plum districts. Certainly the varieties grown in the Experiment Station orchards at Morgantown are slower in coming into bearing than are the same varieties in Michigan and New York. Since varieties of the European plum can be grown at least fairly well, there really is little reason for the cultivation of the many varieties of native and Japanese plums. Most Japanese varieties bloom so early that they are killed by frosts.

Varieties of Plums

A NUMBER of varieties are being tested. The list includes Abundance, Bradshaw, Burbank, Early Gold, French Prune,* German Prune,* Gold, Italian Prune,* Moore's Artic,* Pearl, Pond,* Red June, Reine Claude, Satsuma, Shropshire Damson,* Stark Green Gage,* and Tatge.

Bradshaw

THE ORIGIN of this variety is obscure. Some have believed it of American origin, but since it is identical with Large Black Imperial it must be of foreign origin. It was named and described by C. M. Hovey in 1846 in his Magazine of Horticulture with the following explanation: "For the want of a name to distinguish a very large and excellent plum, exhibited for three or four years in succession by E. E. Bradshaw, Esq., Charlestown, we have called it the Bradshaw plum." It was really the Large Black Imperial, so the name Bradshaw is in-

*Varieties in bearing upon which a report can be made. Other varieties were not old enough to bear at the time this report was prepared.

correct according to the rule of priority. Bradshaw is now one of the leading varieties in the Eastern States.

The fruit is medium to large and oval in shape. Skin is thin, somewhat tough, and of a dark, reddish-purple color overspread with a thick bloom.* Flesh is dull yellow, juicy, fibrous, tender, sweet, pleasant, good in quality. Stone is semi-free. It ripens early in August, is a good keeper, and ships well. It is very subject to brown rot.

The tree is large, vigorous, somewhat bushy, hardy, and productive. It is late in coming into bearing.

Bradshaw seems to be worthy of trial in West Virginia because of its good tree characters and large, attractive fruits.

Reine Claude (Green Gage)

REINE CLAUDE is the principal variety of a group of plums known as the Reine Claude group. Where it originated no one knows. The group has been recognized and described by pomological writers for three centuries. Its later history is better known. It was named after Queen Claudia, wife of Francis I of France, the fruit having been introduced into that country during their reign. The name Green Gage comes from the fact that it was introduced into England by the Gage family, prominent English horticulturists. Because of its great popularity it was brought to America by the early colonists. Reine Claude, the principal variety of the group, is one of the standard Green Gages grown in America.

Fruit is medium in size, roundish-oval in shape. Skin is tough, yellowish green, becoming a golden yellow at full maturity, overspread with a thin bloom. The exposed side is often mottled with red. Flesh is greenish yellow to golden-yellow, juicy, firm, sweet, mild, and of the highest quality. Stone is semi-clinging. Fruit often cracks badly if rain occurs at ripening time. It ripens late in August.

Tree is of medium size and vigor, round-topped, hardy, and productive, but seems to be quite susceptible to sun-scald.

Reine Claude is a good variety for the local trade because of its high quality and productiveness.

*A delicate, white, somewhat powdery substance on the surface of the fruit.

Shropshire (Damson)

SHROPSHIRE has been under cultivation for a long time, being an English variety which originated sometime in the seventeenth century. American writers of pomology did not mention it, however, until the nineteenth centry. It was recommended for planting by the American Pomological Society in 1875.

Fruit is of good size for a Damson and is oval in shape. Skin is thin, tender, of a purplish-black color covered with thick bloom. Flesh is yellow, juicy, firm, tart, and sprightly. Stone is clinging. It may be eaten raw when fully ripe, but its chief value is in its culinary qualities. It ripens in September.

Tree is large, vigorous, hardy, and very productive. It is not so thick-topped as other Damsons. Leaves are very subject to leaf spot.

Shropshire is probably the best known of all the Damsons and should be in every home market orchard.

Italian Prune

THE ITALIAN PRUNE originated in Italy at least a century ago and is one of the common varieties. It was grown in England prior to 1831 since the catalog of the London Horticultural Society of that date lists it. William Prince described it a year later as being an excellent prune recently introduced from Europe. It is now one of the most widely grown of all plums, a leading variety on the Pacific Coast as well as on the Atlantic.

The fruit is medium in size and long-oval in shape. Skin is thin, somewhat tough, of a dark purplish color overspread with a thick bloom. Flesh is greenish yellow, juicy, firm subacid, and of very good quality. Stone is free. It ripens the latter part of September, and keeps and ships well.

The tree is medium in size, vigorous, spreading, low-topped, comes into bearing quite early, and is productive. It seems to be somewhat sensitive to soils and does not stand dry, hot weather well.

Italian Prune is popular because of the many good all-round qualities of its fruit. It is excellent when stewed and makes a very good canned product, and is one of the leading varieties in the prune growing states of the Pacific Northwest. When fully ripened it is excellent for eating raw. Italian Prune can safely be planted for the local market in West Virginia.

STERILITY OF TREE FRUITS

MANY of the varieties of tree fruits when planted in solid blocks set poorly or not at all, due to the fact that they are more or less self-sterile, that is, their own pollen will not fertilize them. This is particularly true of varieties of the apple, pear, plum, and sweet cherry. With such varieties adequate provisions must be made for cross-pollination, if good crops are to be obtained. This is done by inter-planting varieties and where necessary, placing bees in the orchard to carry the pollen from one variety to another. Generally speaking, a row of the pollinator to four or five of the main variety will result in sufficient cross-pollination to set a crop provided, of course, bees are present in sufficient numbers. It should be emphasized that fruit pollen is not carried by the wind, but by insects, particularly bees.

Best Results by Inter-Planting

Choose Varieties That Will Cross

Many varieties of apple are self-fertile. Grimes, Jonathan, Northwestern, York, Ben Davis, Transparent, and Wealthy, seem to be able to set enough fruit for a crop without cross pollination. Delicious sets poorly when planted by itself, while Black Twig, Winesap, and Stayman set poorly or not at all when planted alone in solid blocks. Grimes, Jonathan, Wealthy, and Transparent are good pollenizers for Delicious. The same varieties with the addition of Delicious are good pollenizers for Stayman and Winesap. Grimes does not seem to be a good pollenizer for Black Twig. A list of pollenizers for Black Twig would include Delicious, Jonathan, Wealthy, and Transparent. York may cross fertilize any of the above varieties, but generally blooms too late for best results.

Most Peaches Self-Fertile

All the standard varieties of peaches are self-fertile except J. H. Hale. This variety consequently must be planted close to others. All the well-known commercial varieties seem to be equally capable of fertilizing the J. H. Hale.

Practically all varieties of sweet cherries are self-sterile. A few varieties are inter-sterile, that is, they will not cross-fertilize each other. The varieties described in this circular are more or less sterile, but will adequately cross fertilize. Tartarian is a particularly good pollenizer.

The varieties of Duke cherries are partially self-sterile. They will set a sufficient number, however, to insure a good crop under normal conditions.

Few of the standard varieties of plums and pears are self-fertile. Shropshire Damson seems to set well when planted by itself, but Reine Claude, Bradshaw, and Italian Prune will set much better in mixed plantings.

The varieties of pears, Bartlett, Keiffer, Seckel, and Winter Nelis, should be interplanted, if maximum crops are to be obtained.

REFERENCES

BEACH, S. A., THE APPLES OF NEW YORK. N. Y. Agr. Expt. Sta. Rpt. 1903.

CHANDLER, W. H., FRUIT GROWING. Houghton Miffling Company. 1925.

GREEN, W. J., AND THAYER, PAUL, VARIETIES OF APPLES IN OHIO. Ohio Agr. Expt. Sta. Bul. 290. 1915.

HEDRICK, U. P., THE PLUMS OF NEW YORK. N. Y. Agr. Expt. Sta. Rpt. 1910.

.... THE CHERRIES OF NEW YORK. N. Y. Agr. Expt. Sta. Rpt. 1914.

.... THE PEACHES OF NEW YORK. N. Y. Agr. Expt. Sta. Rpt. 1916.

.... THE PEARS OF NEW YORK. N. Y. Agr. Expt. Sta. Rpt. 1921.

.... CYCLOPEDIA OF HARDY FRUITS. The Macmillan Company. 1922.

Other bulletins and circulars published by the Experiment Station, College of Agriculture, which are of interest to orchardists and fruit growers include:

Bul. 174, The Fertilization of Apple Orchards, I.

Bul. 183, Fertilizing Peach Trees.

Bul. 203, The Fertilization of Apple Orchards, II.

Bul. 209, Dusting vs. Spraying in the Apple Orchard.

Bul. 211, Hardiness of the Fruit Buds of the Peach.

Bul. 214, Effect of Height of Head on Young Apple Tree Growth and Yield.

Cir. 37, Fertilizing Peach Trees (Abstract of Bulletin 183).

Cir. 54, Orchard Spraying in West Virginia.

Come to Morgantown

An invitation is extended to West Virginia farmers and fruit growers to visit the experimental orchards of the College of Agriculture, West Virginia University, and inspect at first hand the varieties of fruits described in this bulletin, as well as learn about results of various cultural methods, systems of pruning, and fertilization practices.

Special Parties

Those who come to visit the farms in small groups while passing through on a vacation or making a special trip can obtain a guide to show them over the farms and explain the experimental work by applying at the Horticulture office in the College of Agriculture (Oglebay Hall).

Farmers' Field Day

Each year a Farmers' Field Day is held during mid-summer at the College farms. This occasion provides an excellent opportunity to see the orchards in production and to learn of the experimental work being done.

Farmers' Week

Another opportunity to visit the orchards and hear the latest discoveries discussed is afforded at the annual Farmers' Week. Pruning demonstrations are usually given at this time, and other practical work such as making spray solutions, grafting, etc., engaged in.

Whether it suits you best to come in Summer or winter, on a special occasion or otherwise, come and avail yourself of the opportunities thus afforded.

Circular 40 February, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

MORGANTOWN

HENRY G. KNIGHT, Director

EFFECT OF WINTER RATIONS ON PASTURE GAINS OF TWO-YEAR-OLD STEERS

Abstracted by

E. A. LIVESAY

This Circular summarizes the most important results and recommendations given in more detail, in West Virginia Experiment Station Bulletin 191 by E. W. Sheets, R. H. Tuckwiller, and A. T. Semple, of the Bureau of Animal Industry, United States Department of Agriculture, and E. A. Livesay of the West Virginia Agricultural Experiment Station. Anyone desiring a copy of this bulletin may secure it upon application to the Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

The finishing of beef cattle in West Virginia is similar to that in the remainder of the Appalachian region, where bluegrass furnishes the fattening rations. The majority of fat cattle shipped from the state are grass-fattened, three-year-old steers. These steers are bought from farmers located in the rougher sections of the same county or nearby counties, where the grass will not fatten heavy cattle. These cattle are bought during the summer as two-year-olds and as soon as their three-year-old steers have been shipped, which is during the months of August and September, they are collected and grazed during the remainder of the grazing season. This fall grazing season extends well up into December in many sections of the state. The steers are then carried through the winter on approximately a maintenance ration. These rations are composed mostly of common roughages, such as corn stover, hays and corn silage. In some cases small quantities of cut ear corn are fed in addition to the hay and stover roughages, and, in other cases, where corn silage makes up the majority of the roughage, either a small quantity of mixed hay or cottonseed meal is fed. There is a portion of these men who still feed such feeds as corn stover and timothy hay. On many farms other feeds, such as silage and legume hay, would give much better results.

OBJECTS

The investigational work reported in Bulletin 191 was taken up with a view of securing information in regard to winter rations for two-year-old steers and their effects upon the pasture gains made the following season. These steers are classed as two-year-olds in the feed lot, but are three-year-olds when sold the following summer or early fall.

DURATION OF EXPERIMENT

This experiment extended over a period of three years, beginning in the early winter of 1919 and closing in the fall of 1922. The cattle were started on feed each year about December 25, and were turned to grass about April 27, or an average winter feeding period of 124 days. They were shipped to market each year during the first half of September. The average grazing period for the three years was 135 days.

CATTLE AND DIVISIONS

Sixty head of native two-year-old steers were used each year. They were considered to be from fair to good feeders, and were grade steers of Aberdeen-Angus, Shorthorn, and Hereford breeding.

The steers were each year divided into six lots of ten steers each. The divisions were made according to beef type, size, and condition, so as to make all lots as nearly equal as possible. All steers were marked with neck straps and ear tags, and individual records were kept.

WINTER FEEDS AND SHELTER

The feeds fed were all home grown except the cottonseed meal, and were all of good physical quality each year with the exception of the mixed hay. While this hay was classed as mixed clover and timothy, it was approximately three-fourths timothy and the third season it was in poor condition, showing it had been cut too late in the season and was considerably bleached. Water and salt were kept before the cattle at all times. All lots were kept in pens in a large barn.

PASTURF

The cattle were all grazed on the same pasture each year. The pasture used is not classed as among the best fattening pastures in the section where the work was conducted. The pasture used was an average bluegrass sod with some white clover.

SUMMARY OF THREE YEARS' WORK, 1919-1922

The average winter feeding period lasted 124 days; the average summer grazing period 135 days; thus making the average annual period for the three years 259 days.

TABLE I.—Summary of Rations, Weights, Gains, Losses, Costs, and Other Items for Each of the Six Lots.*

Items Considered	Lots					
	I	II	III	IV	V	VI
Number of steers per lot	10	10	10	10	10‡	10
Average winter rations (lbs.):						
Mixed hay	18.3	....	....	....	....	7.3
Wheat straw	....	....	....	....	5.8	....
Corn silage	....	28.9	38.7	29.5	24.8	24.8
Cut ear corn	2.0	....	....	....	....	....
Cottonseed meal	....	....	....	1.5	1.0	....
Average initial weights (lbs.)	962	961	965	964	966	965
Average spring weight (lbs.)	980	952	1,031	1,014	1,052	1,024
Average winter gains or losses (lbs.)	18	–9	66	50	86	59
Average final weights on farm (lbs.)	1,292	1,298	1,314	1,326	1,310	1,301
Average summer gains (lbs.)	312	346	283	312	259	277
Ave. total winter-summer gains (lbs.)	330	337	349	362	344	336
Average cost of wintering	$22.88	$10.78	$14.40	$15.62	$14.85	$17.41
Average weights at Jersey City† (lbs.)	1,223	1,189	1,216	1,227	1,220	1,199
Average drift† (lbs.)	71	75	75	75	61	80
Average percentage drift† (lbs.)	5.5	5.9	5.8	5.8	4.7	6.3
Average dressing percentage†	55.6	56.9	57.0	57.1	56.3	57.6

*The cost of wintering is based upon the following costs of feeds: mixed hay $18.00 per ton; wheat straw $7.00 per ton; corn silage $6.00 per ton; cottonseed meal $50.00 per ton; and ear corn $0.70 per bushel.

†For first and second year only.

‡Only eight steers in 1920-21 as two died during the winter.

DISCUSSION OF RESULTS

Winter Rations and Gains or Losses

From the data of Table I. it is shown that the average winter gains or losses for the three winters ranks as follows: Lot V., 86 pounds; Lot III., 66 pounds; Lot VI., 59 pounds; Lot IV., 50 pounds; Lot I., 18 pounds, and Lot II., —9 pounds. This would indicate that a daily ration of 28.9 pounds of corn silage (Lot II.) is almost sufficient to maintain two-year-old steers weighing 960 pounds, during a winter period of 124 days, and that the other rations used will produce small gains over the same period. The gain being rather small in the case of Lot I., receiving a ration of 18.3 pounds of mixed hay and 2 pounds of cut ear corn, while the gains of Lots III., IV. and VI. are approximately equal, 66, 50, and 59 pounds, respectively. Therefore, the rations fed Lot III. (38.7 lbs. corn silage), Lot IV. (29.5 lbs. corn silage and 1.5 lbs. cottonseed meal), and Lot VI. (7.3 pounds mixed hay and 24.8 pounds corn silage), proved to be of about equal value in so far as winter gains are concerned. The ration fed Lot V. (5.8 pounds wheat straw, 25.25 pounds corn silage, and 1 pound of

cottonseed meal), proved superior to all other rations in so far as winter gains are concerned.

Pasture Gains and Total Gains for the Year

From the data of Table I. it is shown that winter gains on two-year-old steers are made at a loss to the pasture gains, because Lot II. made the greatest pasture gain (346 pounds) of any lot, while Lot V. made the smallest pasture gain (258 pounds). In other words, when there is a difference in winter gains we can expect the steers making the lighter winter gains to make the heavier pasture gains. The total gains for the year do not differ materially, since the difference between the lightest gains, made by Lot I. (330 pounds), and the heaviest gains, made by Lot IV. (362 pounds), is only 32 pounds per steer. Had these steers been marketed one month earlier this difference would have been much greater, as was shown by the weights of lots taken during the mid-summer.

Cost of Wintering and Grazing

Table I. gives the average cost of wintering each lot for the three years. However, there is such a variation in the cost of feeds from year to year, and even the same year in different sections of the state, that one hesitates in giving the cost of the various rations. The one thing which stands out in the cost of these rations is the value of corn silage in making up the major portion of the ration. Corn silage not only cheapened the rations, but when figured back to an acre basis it will carry many more cattle through the winter. The cost of grazing was identical for all lots and no attempt is made in regard to this cost item since it is variable even in the same locality and very variable in different sections of the state. All cost items should be calculated from an individual standpoint.

CONCLUSIONS

1. Corn silage alone is a very economical and satisfactory winter ration for two-year-old steers. A ration of mixed hay and cut ear corn is a very costly winter ration, in comparison to rations where corn silage makes up a large amount of the ration.

2. Various winter feeds have little, if any, effect upon the gains made by two-year-old steers the following summer on blue grass pasture. However, the amount of gains made during the winter feeding period has a direct bearing on pasture gains. Light winter gains as a rule mean heavier pasture gains and vice-versa.

3. A ration of about 30 to 35 pounds of corn silage, depending upon quality, will maintain 950 to 1,000 pound steers during a winter period of 124 days and is one of the most economical rations that can be fed.

4. It is a question of the time of marketing three-year-old grass-fat steers as to whether it will pay to feed a sufficient ration to produce 50-100 pounds of gain during the winter feeding period. The fleshing of the cattle must also be taken into consideration.

If three-year-old steers are to be carried on grass until the first half of September before marketing, it is not profitable as a rule to feed a ration which will produce from 50 to 100 pounds of gain, unless the cattle are in a very thin condition.

If three-year-old steers are to be marketed from grass the latter part of July or the first half of August, the additional finish brought about by winter gains of from 50 to 100 pounds may be profitable.

For late marketing of three-year-old steers from grass, it is better to winter them on as cheap a ration as possible, and feed this ration in an amount which will approximately maintain their weights during this period, unless steers are thin when the winter feeding begins.

5. Steers wintered on corn silage will make just as rapid gains on grass as those wintered on dry roughages.

Lot 1 at the Beginning of the Third Year's Work; Winter Ration: Mixed Hay 15 Pounds, and Ear Corn 2 Pounds.

Lot 1 at the End of the Third Year's Work; Average Gain per Steer, 307 Pounds.

Lot 2 at the Beginning of the Third Year's Work: Winter Ration: Silage 28 Pounds.

Lot 2 at the End of the Third Year's Work; Average Gain per Steer, 378 Pounds.

Lot 3 at the Beginning of the Third Year's Work; Winter Ration: Silage 36 Pounds.

Lot 3 at the End of the Third Year's Work; Average Gain per Steer, 378 Pounds

Lot 4 at the Beginning of the Third Year's Work; Winter Ration: Silage 30 Pounds, Cottonseed Meal 1.5 Pounds.

Lot 4 at the End of the Third Year's Work; Average Gain per Steer, 391 Pounds.

Lot 5 at the Beginning of the Third Year's Work; Winter Rations: Silage 25 Pounds, Straw 6 Pounds, and Cottonseed Meal 1 Pound.

Lot 5 at the End of the Third Year's Work; Average Gain per Steer, 377 Pounds.

Group Picture Showing the Six Lots of Steers Shown in the Preceeding Pictures at the End of the Summer Grazing Period.

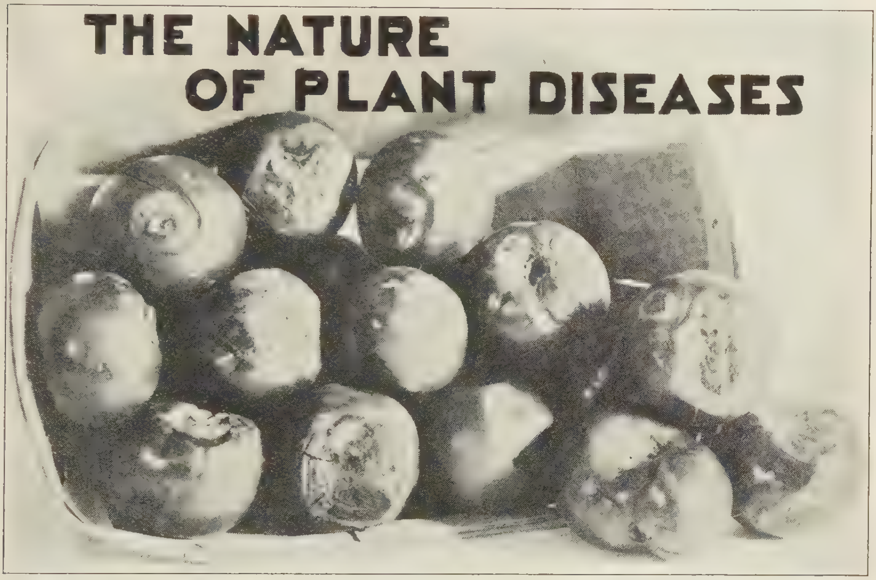
Circular 41 June, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director

MORGANTOWN



By E. C. SHERWOOD

The loss every year from plant diseases amounts to many millions of dollars, yet it is probably safe to say that the nature of these diseases is not understood generally. Growers are usually content with mere information regarding the established methods for combatting the prevalent diseases. Too often, however, they do not become concerned about control measures until serious damage is threatened. It is usually too late then to apply remedies, since most diseases must be prevented rather than cured.

The great importance of this principle cannot be fully appreciated without a knowledge of the true cause and nature of fungous diseases. This circular has been prepared for the purpose of aiding the grower in acquiring such knowledge, and to give a better understanding of the underlying principles of plant disease control methods.* A better

*The writer is indebted to Mr. C. H. Hanson, Specialist in Visual Education, Office of Cooperative Extension Work, United States Department of Agriculture, Washington, D. C., for the photographic work necessary in the preparation of the illustrations used in this circular.

knowledge of the principles which underlie our more common methods of controlling plant diseases will lead to their more intelligent application.

A knowledge of the cause and nature of fungous diseases can best be obtained by means of special study with the aid of the compound microscope (See Figure 1). Objects viewed through this instrument are magnified hundreds of times so that many things which are ordinarily invisible can be seen readily. On account of the high magnification, very small objects only can be viewed through the microscope; consequently when the object is too large, it is usually studied by means of cross sections.

A loaf of bread may be used to illustrate the method of making cross sections. A slice is cut from the loaf and laid upon a table. By looking down at the slice, one sees a cross section of the loaf. In a simlar manner with the aid of a razor or appropriate instruments used in the laboratory, very thin slices may be cut from plant parts for examination. In

Fig. 1.—Using the Compound Microscope.

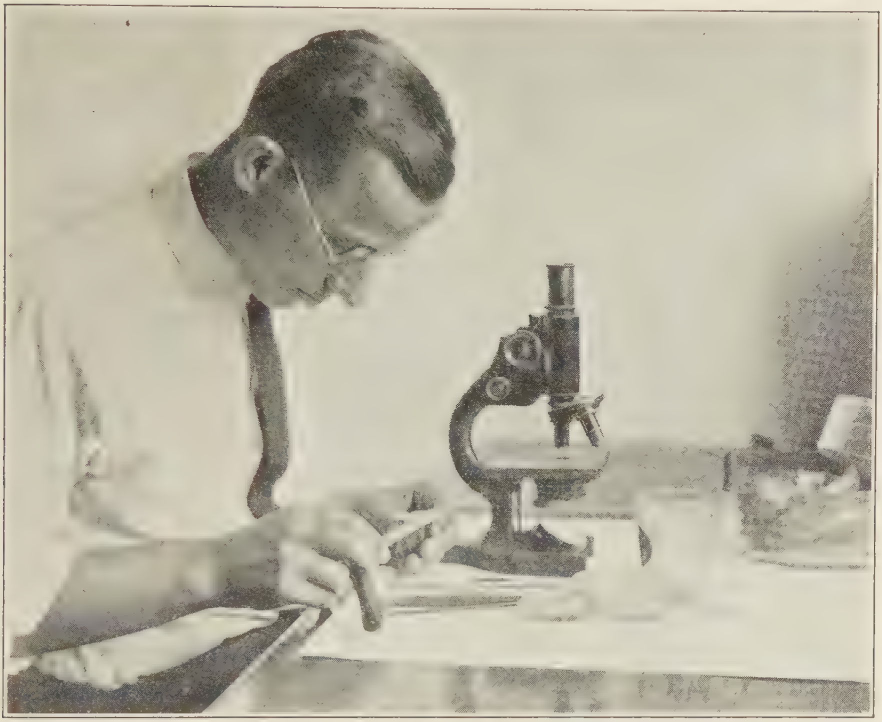


Fig. 2.—Cutting Thin Cross Sections of a Cucumber for Examination Under the Microscope.

Figure 2 the operator is shown cutting a cross section from the end of a strip of cucumber with a razor blade. These minute slices are laid upon a glass slide which is then placed under the microscope. A view of the cross section of the cucumber is obtained by looking down through the tube of the instrument. Sections of other plant parts may be made and observed in a similar way. Such cross sections can be made so thin that, with the aid of strong light reflected through them, it is possible to see very small objects which might be contained within the interior of the plant tissue.

Such methods of investigation reveal the fact that the causal agents of fungous plant diseases are *really plants themselves;* hence some means must be devised for their destruction if they are to be prevented from causing diseases. This cannot be done without a knowledge of their habtis of growth and the manner in which they affect other plants. The growth habits of such organisms are found to differ in many respects from those of ordinary plants.

These differences are explained more easily if we consider first one

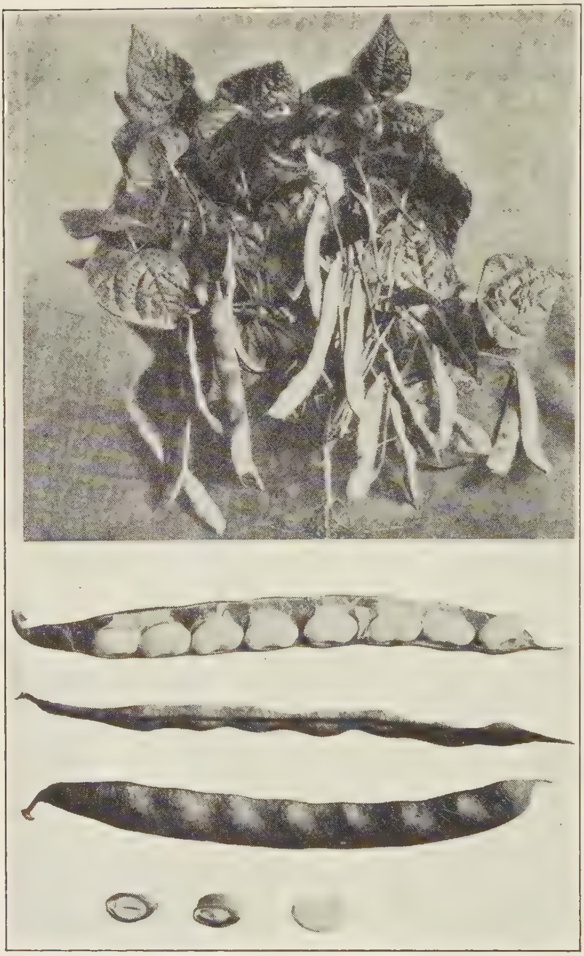


Fig. 3.—The Garden Bean.

of the more familiar plants, such as the garden bean (see Firge 3), and learn how it is able to live and propagate itself. Observe that the plant body consists of roots, stem, and leaves, and that it produces a fruit called a pod. Within the pod the beans or seeds are borne. It is common knowledge that when a bean is planted, it germinates and produces a new bean plant. After a period of growth the plant again produces seed.

No growth can take place, however, without a supply of food. The manner in which such plants as the bean are able to obtain their food is conveniently illustrated by the diagram shown in Figure 4. The roots absorb water and other food materials from the soil; these are then carried up through the water vessels of the stem and spread out through the leaves by means of the veins. Water taken from the soil is carried up to the leaves where it is combined with carbon dioxide which comes from the air. As a result sugars and starches are formed. This building up of food materials is accomplished by the green-coloring matter of the leaves through the agency of sunlight. This green-coloring matter is known as *chlorophyll*, and plants which possess it, by using the energy of sunlight, are able to manufacture their own food and lead an independent existence.

For the next step, let us consider a common toadstool (see Figure 5). At first glance the toadstool appears to be similar in its general form to that of the bean plant. Below the ground line are structures which appear to be roots, whereas above these arises a stem which is expanded at the top into a cap.

There are very important differences, however, between the two plants. The rootlike structures are not true roots, but really form the principal parts of the plant body. The toadstool above the ground, which is the only part of the plant usually seen, is in fact a *fruiting structure*, the cap of which corresponds rather roughly to the pod of the bean.

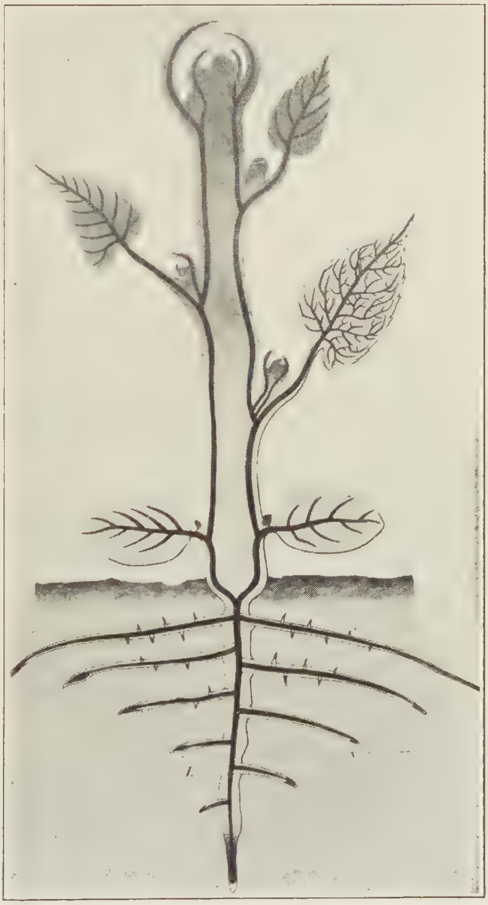


Fig. 4.—Diagram Illustrating Passage of Water and Other Food from Roots Throughout a Plant.

In the next illustration (see Figure 6) a part of the cap is cut away to show the gills, and a portion of one of the gills is shown highly magnified. Observe that each projection from the sides of the gill has four tiny stalks at the tips of which small oval-shaped bodies are attached. These are the *seed bodies* of the toadstool. Each one of these, if planted in the proper place, and subjected to suitable conditions of temperature and moisture, will germinate and produce a new toadstool plant. After a period of growth, the fruiting structure, or toadstool, is again developed and a new crop of seed bodies is produced. Thus, in one important respect, the toadstool plant is similar to the bean plant, since it produces a fruit and "seed." These "seeds" are quite different from those of the bean, however, and are called *spores*.

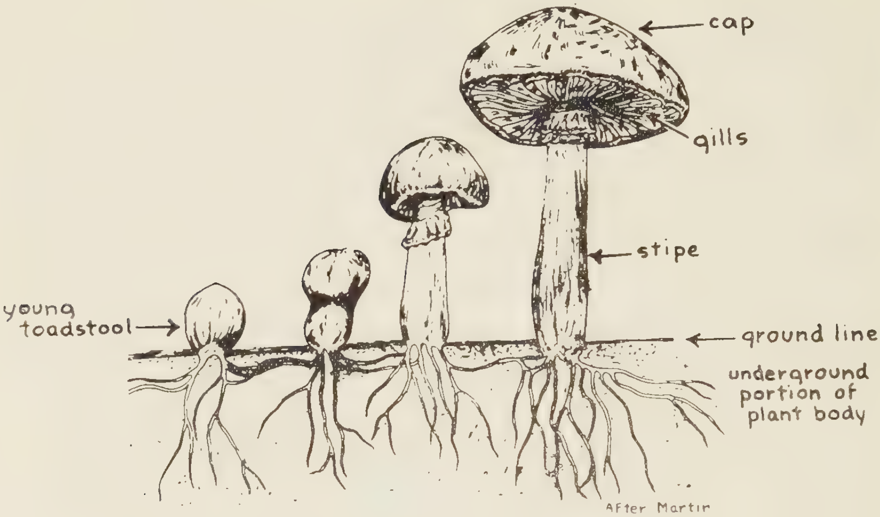


Fig. 5.—Stages of Development of the Toadstool.

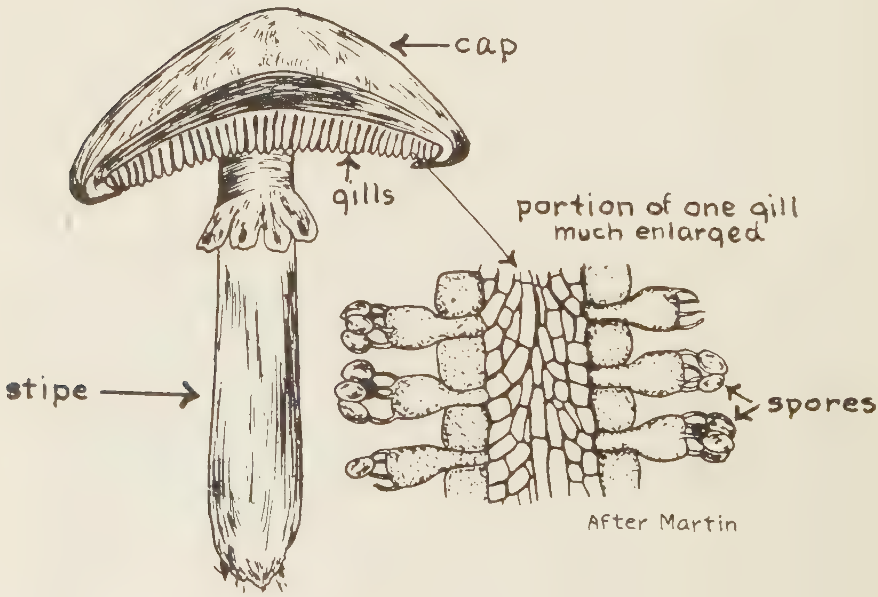


Fig. 6.—Toadstool Spore Production.

The question that now arises is how the toadstool obtains food for

growth. No part of the plant corresponds to the leaves of the bean, and no part of the plant contains any of the green-coloring matter necessary for food making. The plant, therefore, is unable to make is own food and consequently must obtain it from a supply already at hand. This is usually in the form of decayed vegetable matter. The real body of the toadstool plant consists merely of a mass of threads, or strands, which are seldom noticed since they grow beneath the surface of the material upon which they live. These strands have the power to absorb this prepared food from the decayed matter. The toadstool belongs to a group of plants known as *fungi* which, on account of the lack of green-coloring matter, cannot make their own food.

After Bergen and Davis

Fig. 7.—The Puffball.

A very similar type of fungus is commonly known as a puffball (see Figure 7). Like the toadstool, the part seen above ground is the fruiting structure, and the fungus body is in this case below the surface of the ground growing upon some sort of decayed matter. It is common knowledge that when the puffball is "ripe" it is filled with a very fine powder. If the ripe puffball is suddendy compressed, a dense cloud of

Fig. 8.—Puffball Spore Discharge When Compressed.

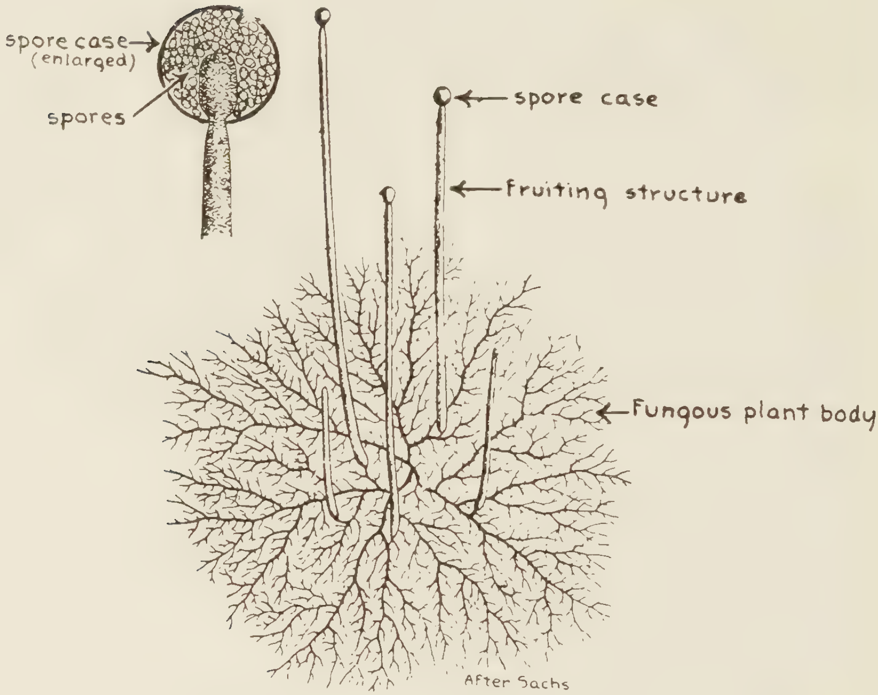


Fig. 9.—A Mold Plant.

this dustlike powder is forced out through the openings in the surface (see Figure 8). Microscopic examination shows that each one of these particles is a spore of the puffball fungus. Immense numbers of these spores are produced. It has been estimated that there are enough in one puffball to produce, under favorable circumstances, a new fungus on every square foot of an area the size of the state of Indiana.

Let us now extend our observations to include one of the common mold plants (see Figure 9). This type of plant is generally found growing upon damp bread, manure heaps, and other masses of decaying matter. Although to the naked eye it appears as a shining cobweb-like mass, it is seen when greatly magnified to consist of a large number of strands, or threads, which have great regularity in their habit of growth. No part of the plant has any resemblance to roots, stem, or leaves. It does not contain any green-coloring matter and, therefore, must obtain all its food from the material upon which it grows. Arising from the central or older region of the growth are the fruiting structures, at the tops of which small spore cases are borne. One of these is shown still more highly magnified and the interior is seen to be closely packed with small

Fig. 10.—Wheat Rust Showing Section of Wheat Plant Leaf with Spores of Rust, and Tissues of Leaf Affected. (After Stakman).

oval-shaped bodies. These are the spores of the fungus, any one of which is capable of germinating and producing a new mold plant.

With the exception of certain forms of plants which are found in the water, we have now considered types of most of the different kinds of plant forms which ordinarily come within the range of common observation; but beyond these limits there is still a great number of forms of plant life that are often unrecognizable as such . In wheat fields during the early part of many seasons, numerous small masses of reddish powder may be seen on the green parts of the plants. This material is easily rubbed off, and to the unaided eye it appears to be merely a surface coating of powder. If a small section of leaf containing one of these small masses is observed with the microscope, however, it is found that

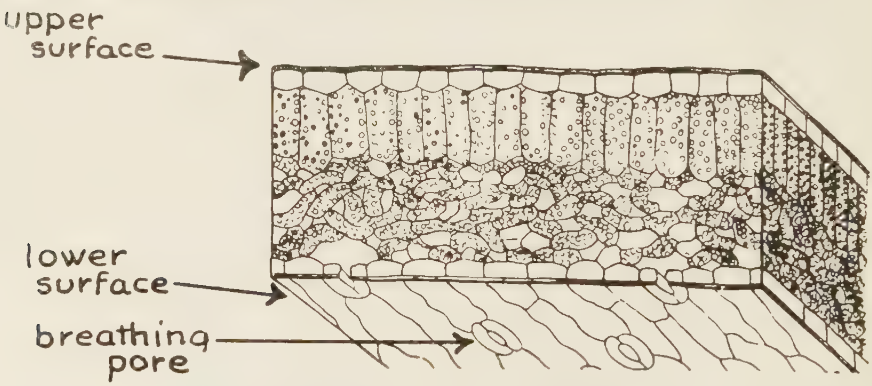


Fig. 11.—Leaf Structure of a Green Plant.

the covering of the leaf has been ruptured, and that the powder has been forced through the opening (see Figure 10).

Though these dustlike particles are so small that they cannot be seen with the naked eye, they are found when sufficiently magnified to resemble tiny seeds borne at the end of small stalks. It is evident that this powder consists of genuine plant structures, but is certain that they are not a part of the wheat plant. In fact, they are the spores belonging to a fungus, the body of which consists of numerous colorless threads, or tubes, which grow about among the tissues of the wheat plant. Now, these fungous threads have the power to absorb juices from the growing plant. These juices contain food which has been manufactured in the wheat plant for its own use from the materials obtained from the air and soil. Thus, this fungus lives entirely upon the food which is made by

the wheat. Since it obtains its food from a *living plant,* such a type of fungus is called a *parasite.* The plant on which it grows is known as the *host.* In the process of their growth parasites in some way injure the host plants. In general terms such injurious effects are called diseases. On account of the resemblance of the spore masses to iron rust, this disease of wheat is commonly known as rust.

From Allen and Gilbert
Fig. 12.—Germination of Corn.

The question may now arise, how is it possible for a fungus to live and develop its body within the plant tissues. A greatly enlarged view of a section of a leaf shows that the interior is made up of a large number of small divisions called cells (see Figure 11). These cells are somewhat irregular in shape and are loosely arranged, leaving many openings between them. Since the fungus threads are much smaller than the openings, they can easily twist about among the cells. Some of the fungi can actually grow through the walls of the cells. Many fungi kill the cells in the process

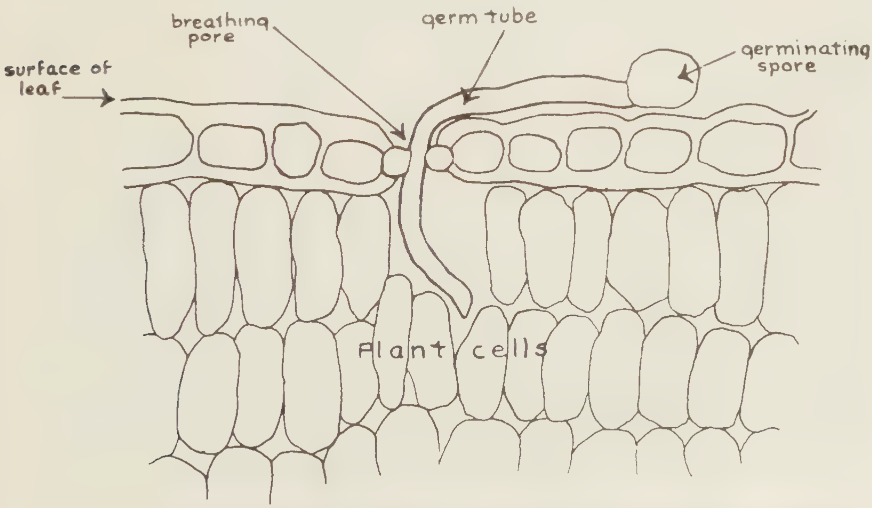


Fig. 13.—Cross Section of Leaf Showing How a Fungus May Enter a Plant.

of their growth, hence the appearance of various rots, spots, blights, and rusts, known as plant diseases.

On the lower surface of the leaf may be observed openings through the skin, or epidermis. These are the breathing pores through which air penetrates to the interior. It has been previously explained that the carbon dioxide of the air is an essential plant food material.

The next question that may arise is how the fungus is able to become established within the plant tissue. Let us consider first how a common field plant becomes established in the soil (see Figure 12). When a grain of corn germinates, the young root breaks through the seed cov-

Fig. 14.—Powdery Mildew on Lilac Leaves.

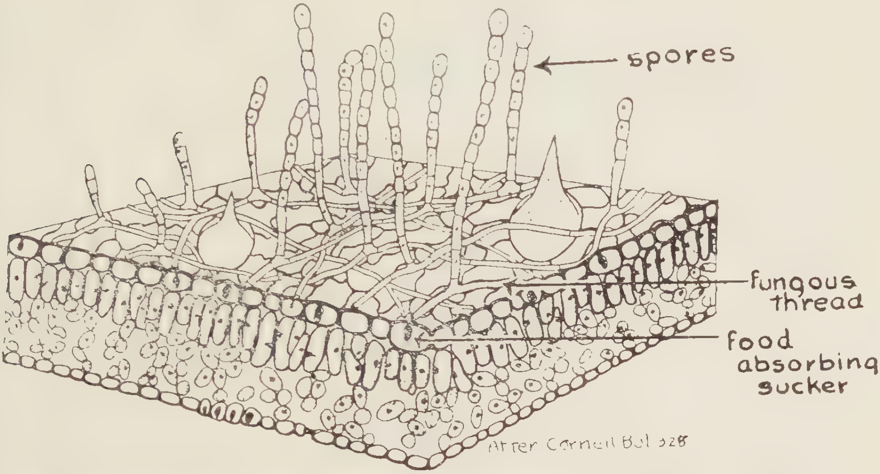


Fig. 15.—Section of a Leaf Showing Surface-growing Habit of a Powdery Mildew.

ings and grows downward, regardless of the position in which the grain might have been placed in the soil. Soon the young root begins to branch and, as growth progresses, secondary roots arise, until finally a large root system is developed in the soil. A young shoot also breaks through the seed covering and pushes its way above ground. The grain contains sufficient food for the seedling until its roots become established and the shoot is already beginning to turn green, due to the development of the chlorophyll.

The next illustration (see Figure 13) shows how a fungus can gain entrance into plant plant tissue. This view is greatly enlarged since the process is not visible to the unaided eye. Spore germination merely consists in sending out a sprout, or germ tube. The germ tube of this spore has grown along the surface of the leaf until it has come to one of the breathing pores. There it has

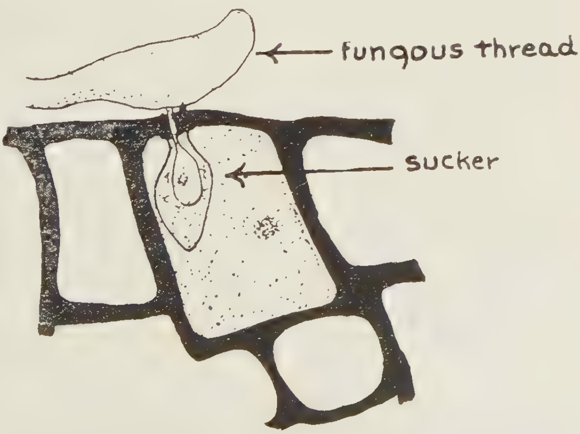


Fig. 16.—Sucker of a Mildew Fungus Penetrating the Surface Cell of a Leaf and Absorbing Nourishment. (Cornell Bul. 328.)

pushed through the opening into the air chamber below. Branching soon takes place and the growing threads twist about among the plant cells from which food is obtained. Growth progresses until a dense network of fungous threads is formed within the leaf. The germ tubes of some fungous spores can penetrate the covering of the leaf without having to pass through the breathing pores, while others are unable to obtain entrance into the interior portions of the plant unless the outer covering is damaged in some way.

Just as in the case of the corn, the spore furnishes food sufficient for the growth of the young fungus until it develops to the point where it is able to obtain its food from the plant cells. Both the seed and the spore require moisture for germination. Being covered with soil, the seed is well protected from the drying action of the sun and air. The spore, however, does not usually fare so well and death will result if a sufficient supply of moisture is not continuously present for growth long enough for the germ tube to reach the interior of the leaf. This explains why several days of continuous damp weather make conditions so favorable for the spread of most fungous diseases and why the popular belief has arisen that the weather causes diseases.

Fig. 17.—Potato Field Showing Plants Affected with Late-blight.

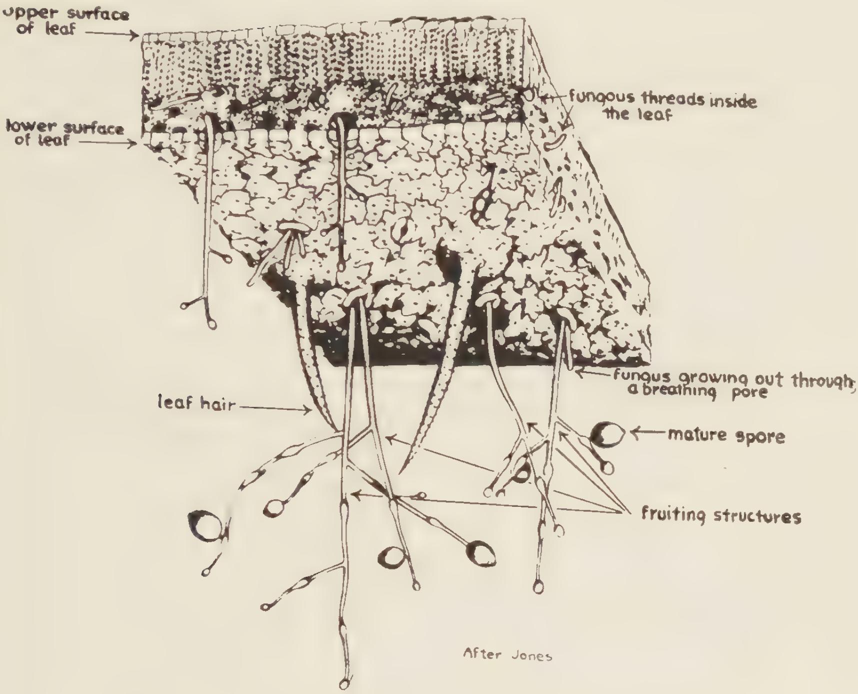


Fig. 18.—Growth Habit of Potato Late-blight Fungus.

As with our more familiar plants, fungi differ greatly in their habits of growth. The following illustrations are given to show how widely different are the life habits of some of the fungi which cause important plant diseases, and to show how disease-control measures are devised. They also serve to emphasize the fact that the control methods recommended are founded upon scientific investigations.

Lilacs are commonly affected with a disease known as powdery mildew (see Figure 14). Roses are often affected with a similar mildew which covers the leaves and young shoots, injuring and often curling the leaves and deforming the stems. When a small section of a leaf affected with a mildew of this type is greatly enlarged (see Figure 15), it is found that the disease is caused by a fungus which grows only upon the surface, merely sending into the outer cells small rootlike suckers by means of which nourishment is obtained. Note the corner surface cell, indicated by the arrow, that has been penetrated by the absorbing sucker. This cell is shown still more greatly enlarged in Figure 16. Such an absorbing sucker, called a *haustorium,* comes in direct contact with the contents of the plant cell. The food which it absorbs is carried into the fungous

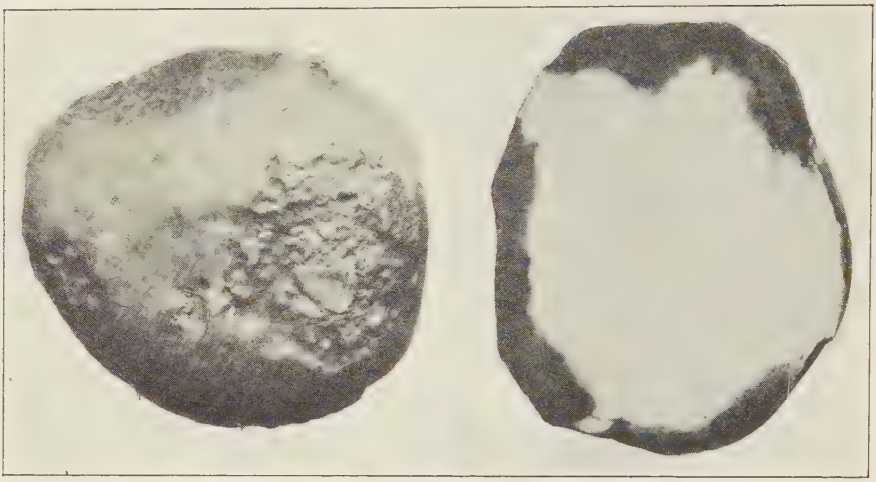


Fig. 19.—Potato Late-blight Tuber Rot.

thread and used by the fungus in the process of its growth. Control of a disease of this type is easily accomplished by spraying or dusting with some material which will kill the fungus, yet not injure the plant upon which it grows. Such a material is called a *fungicide.*

A fungus having a different growth habit causes an important disease of potatoes known as late-blight (see Figure 17). Examination of a greatly enlarged section of a diseased potato leaf (see Figure 18) shows that the organism in this case grows within the tissue. Some of the fungous threads may be observed among the cells of the edge of the leaf shown in cross section. During the process of growth, the fungous threads destroy the cells with which they come in contact and, as the fungus spreads through the tissue, the effect upon the plant is seen in the form of a blight. Fruiting stalks grow out into the air, principally from the lower surface, and mature spores are soon produced. The spores are shed as soon as mature, and the fruiting stalks continue growth for a time, bearing a succession of spores. Fruiting stalks and spores are seen in the illustration in various stages of development.

These spores are distributed over the plants in various ways. If moisture is present, they promptly germinate, set up new infections, and another crop of spores is soon developed. The whole time necessary for this complete process is only about ten to fourteen days if the weather is favorable. Since this procedure is continuous and immense numbers of spores are produced, it is not surprising that the blight develops with exceedingly great rapidity.

Some of the spores fall upon the ground and, upon being washed through the soil by rains, come in contact with the potatoes. The resulting infection causes the well-known late-blight rot of the tubers (see figure 19). The fungus can overwinter in the diseased tissue. When such diseased potatoes are planted, the fungous threads grow into the young sprouts and are carried up with them as they develop. Upon being exposed to proper conditions, the organism begins to fruit. From small centers here and there through the patch the disease may soon become general and destructive.

It should be clear from this study that spray materials applied to the plants serve only to kill organisms when they fall upon the surface and cannot be expected to destroy fungi which are growing within the interior of the tissues. Anything, at least as far as known at the present time, that could reach the fungus and kill it would also destroy the plant. Hence, methods to control diseases caused by such parasites must be directed toward *preventing the fungus from ever becoming established within the plant.* This is accomplished by spraying, provided the application is made before the spores can germinate and send their germ tubes into the interior. It is important, therefore, to spray before the spores reach the plant, since they are capable of germinating and infecting the plant within a few hours.

The next diagram (see Figure 20) represents a cross section of a tomato leaf affected with the disease known as Septeoria left spot. The fungus which causes this disease produces its fruiting structures in the

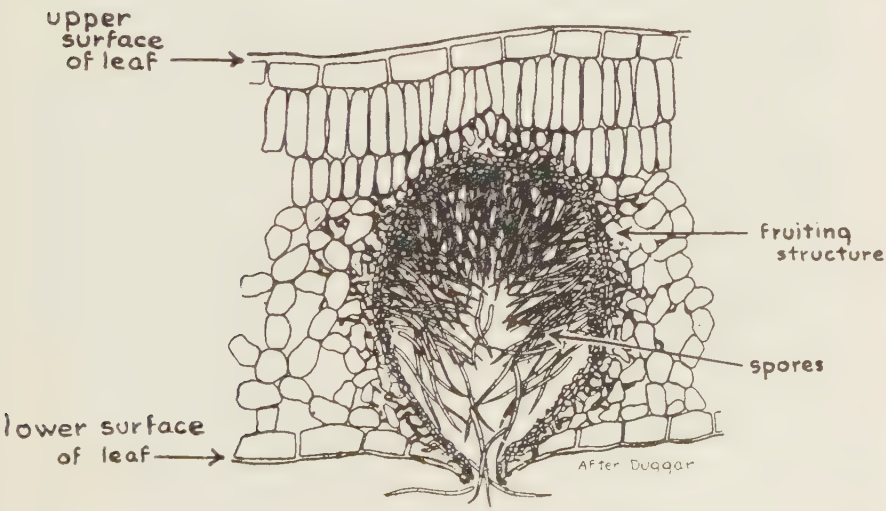


Fig. 20.—Spore Production of the Tomato Leaf-spot Fungus.

Fig. 21.—Apple Scab on Fruit (After Wallace.)

interior of the leaf. In the cross-section view, the fruiting body appears to be only an opening, but in reality its shape is very much like a flask. The long cylindrical spores are borne on very short stalks growing from the inner wall. The fruiting body is packed full of these spores and when mature, they are discharged through a small opening at the surface of the leaf. Carried by various ways to other leaves, the spores germinate upon

Fig. 22.—Apple Scab on Leaves (After Wallace).

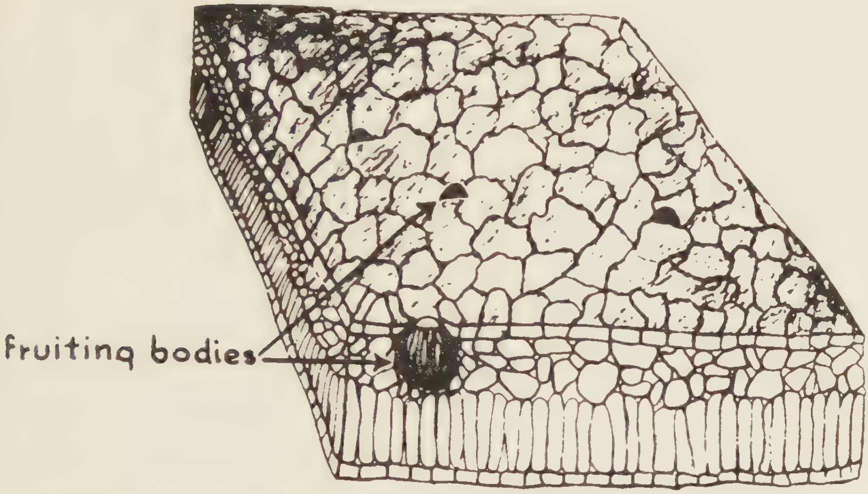


Fig. 23.—Section of Leaf Showing Winter Fruiting Bodies of the Apple-scab Fungus.

the surface of the plant. The germ tubes must penetrate the outer covering to cause infection. Spores developed in the latter part of the season live over winter in the old diseased vines. When carried to the growing tomato vines in the spring, germination and infection take place.

The next illustration (see Figure 21) shows the appearance upon the fruit of the important disease of the apple known as scab. The loosening and uplifting of the skin caused by the growth of the fungus gives the appearance of a whitish papery band around the darker central portion of the spots. The fungus which causes this disease is found to have a complicated life history, inasmuch as *two kinds of spores* are produced.

It is also important to note the appearance of the disease on the leaves (see Figure 22), since they serve to carry the fungus over the winter. After the diseased leaves have fallen and begun to decay, the fungous threads grow through the leaf tissue and winter fruiting bodies begin to form. These fruiting bodies are almost spherical in shape and are embedded in the tissue of the leaf, usually protruding sufficiently to form small dome-shaped pimples on the surface. These pimples are sometimes large enough to be easily visible to the unaided eye.

The next illustration (see Figure 23) is an enlarged view of a portion of a leaf containing several of these structures. Three of them are shown protruding far enough to be visible on the surface. The cross-section view of the edge of the leaf shows the location of the fruiting body in the tissue.

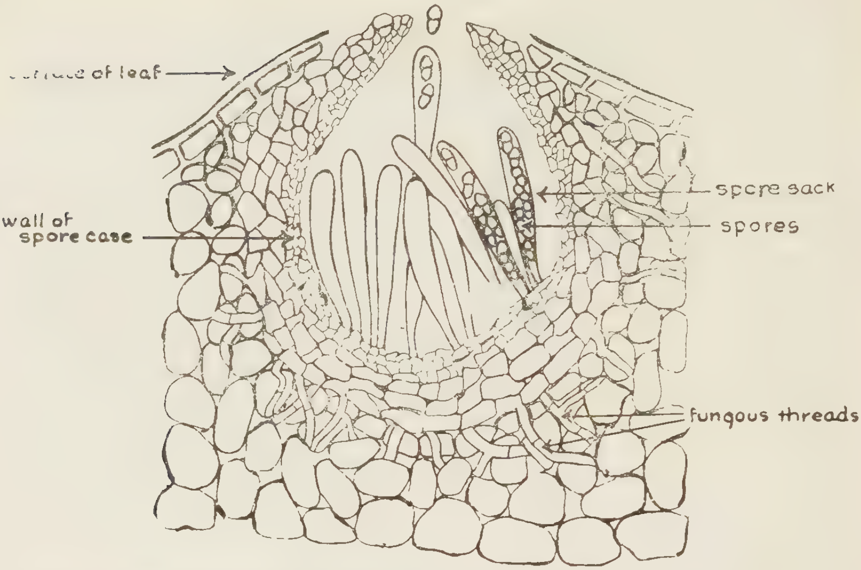


Fig. 24.—Cross Section of Winter Fruiting Body of the Apple-scab Fungus.

A very highly magnified view of a cross section of one of these fruiting bodies (see Figure 24) shows that within the structure there are a number of elongated sacks, or tubes, attached to the wall, and that within these the winter spores are borne. These spores become mature in the spring about the time the blossom buds of the apple trees are opening. During the first rainy period after maturity, the spores are forcibly discharged into the air from the fruiting body and, being extremely light, are carried by air currents to the opening buds. The spores do not all mature at one time, hence discharges may take place after each rain for a month or more.

The spores germinate by putting out a germ tube which very soon penetrates the surface covering of the leaf or fruit, thus establishing infection. The germ tubes develop into a dense system of branching threads, but the entire growth at this time is almost entirely just under the skin (see Figure 25). Within about two weeks a cushion-like growth is formed, from which arises short stalks. These are pushed through the ruptured skin and bear the *summer spores.* These spores mature very rapidly and, when carried to other leaves and fruits, produce new scab spots. Successive crops of summer spores are thus developed during the season; the quantity of spores and the rapidity with which they are produced depending on conditions of moisture and temperature. The scab-infested leaves then serve to carry the fungus over the winter again.

Let us now consider how control measures for this disease are based upon the life history of the fungus. It should be observed that after infection takes place from the *first discharge* of winter spores, the developing leaves and fruit are exposed for some time to *two sources of infecfection*,—winter spores from the old leaves, and summer spores from new diseased areas. The foundation for the successful control of scab, therefore, lies in preventing infection from the first discharge of winter spores. To accomplish this, the first spray must be applied in advance of the first spore discharge. Then, if protective sprays are given at proper intervals during the period winter spore discharges occur, little trouble will be experienced from later infections caused by summer spores.

Another very important disease of the apple (see Figure 26), known as cedar rust, or apple rust, is caused by a fungus which has a still more complicated life history, inasmuch as it requires another kind of plant, the red cedar, for one stage of its existence. Consequently, there can be no apple rust unless the cedar is present in the same locality.

The greatest damage from this disease, however, is usually due to the effect on the leaves (see Figure 27), since they are often so generally and severely affected that much premature dropping occurs.

The next illustration (see Figure 28) shows a highly magnified cross section through one of the rust spots on the leaf. The spores of the rust fungus are produced in cup-shaped fruiting bodies on the under surface of the leaf. When mature, the fruiting bodies open and discharge their spores. These spores are incapable of causing infection on

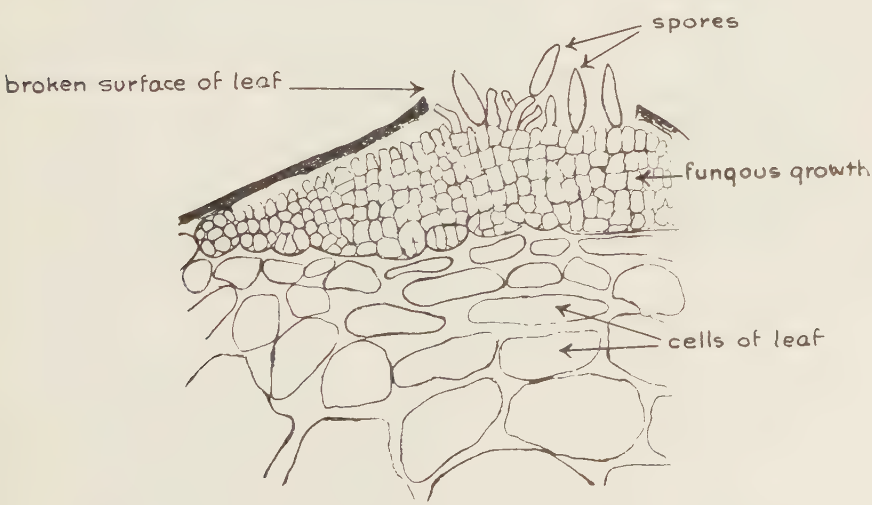


Fig. 25.—Summer Spore Production of the Apple-scab Fungus.

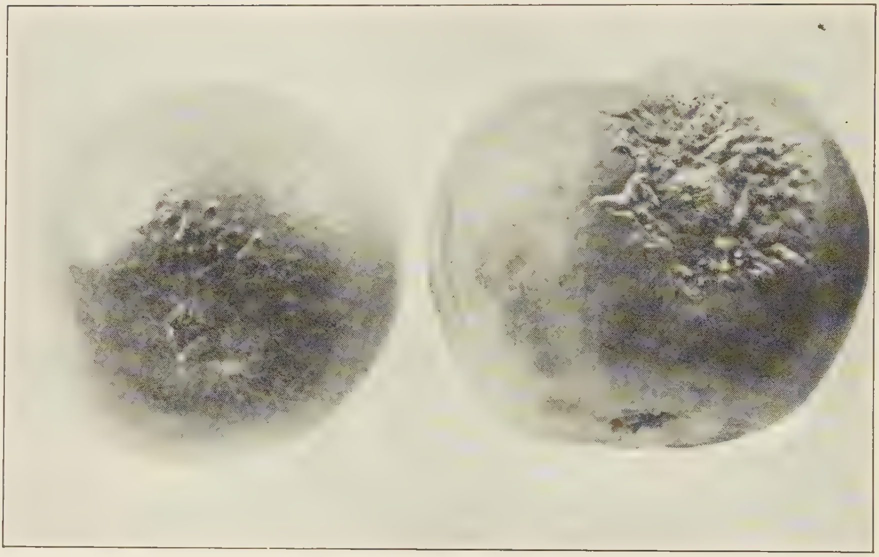


Fig. 26.—Cedar Rust on Apple.

any part of the apple, but when carried by wind to the red cedar, they germinate, set up infection, and the result of the fungus growth is to cause the formation of galls known as cedar apples (see Figure 29). These galls develop very slowly, however, and do not reach full size until the second fall after the spores from the apple leaf are carried to the cedar. The next spring, then, small brown horns push out over the surface. Under the influence of the spring rains, these horns become greatly swollen and have the appearance of jelly-like tendrils (see Figure 30).

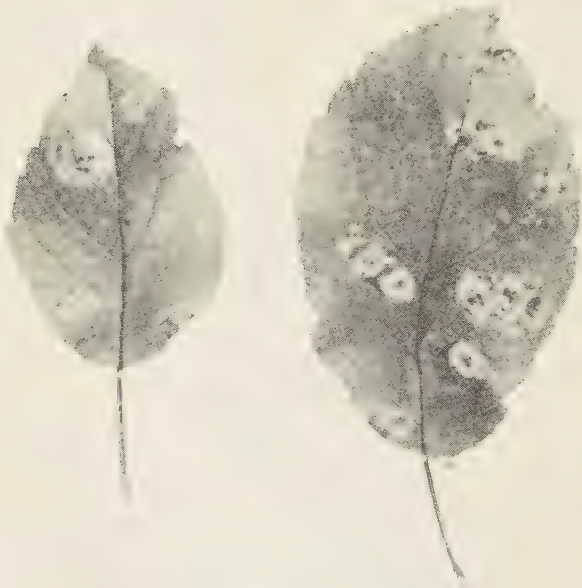


Fig. 27.—Cedar Rust on Apple Leaves.

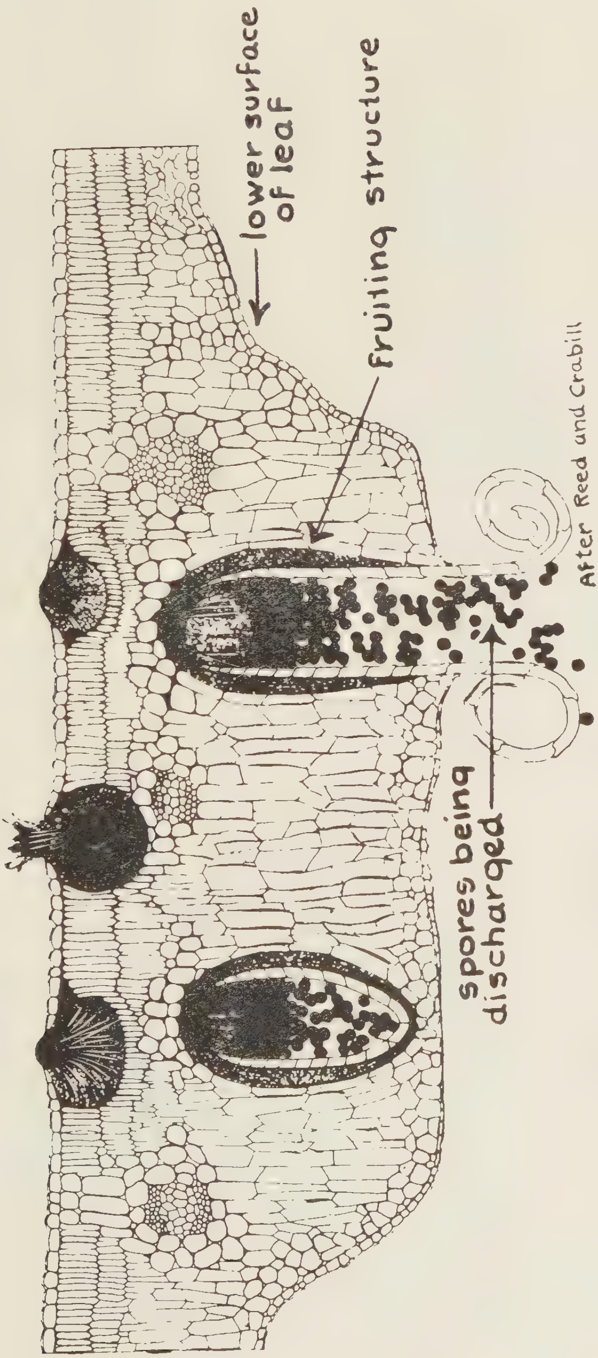


Fig. 28.—Cross Section of Apple Leaf Showing Cedar Rust Spore Production.

Fig. 29.—Cedar Galls.

If a highly magnified section of one of these little horns is observed (see Figure 31), it is found to be composed of another kind of spores. These appear as small black objects in the illustration, and it should be noted that they are attached by means of long stalks. They do not become detached, but germinate in the jelly-like substance just as they are situated. A peculiar germ tube is first produced, and upon this another kind of spore is developed. These, when mature, are discharged into the air. Now, these spores can not infect the cedar, but when carried to the apple trees by air currents, are capable of germinating and reproducing the disease upon the leaves and fruit.

Fig. 30—Cedar Gall Sending Out Spore Horns After a Spring Rain.

In considering the life history of this fungus from the standpoint of the control of

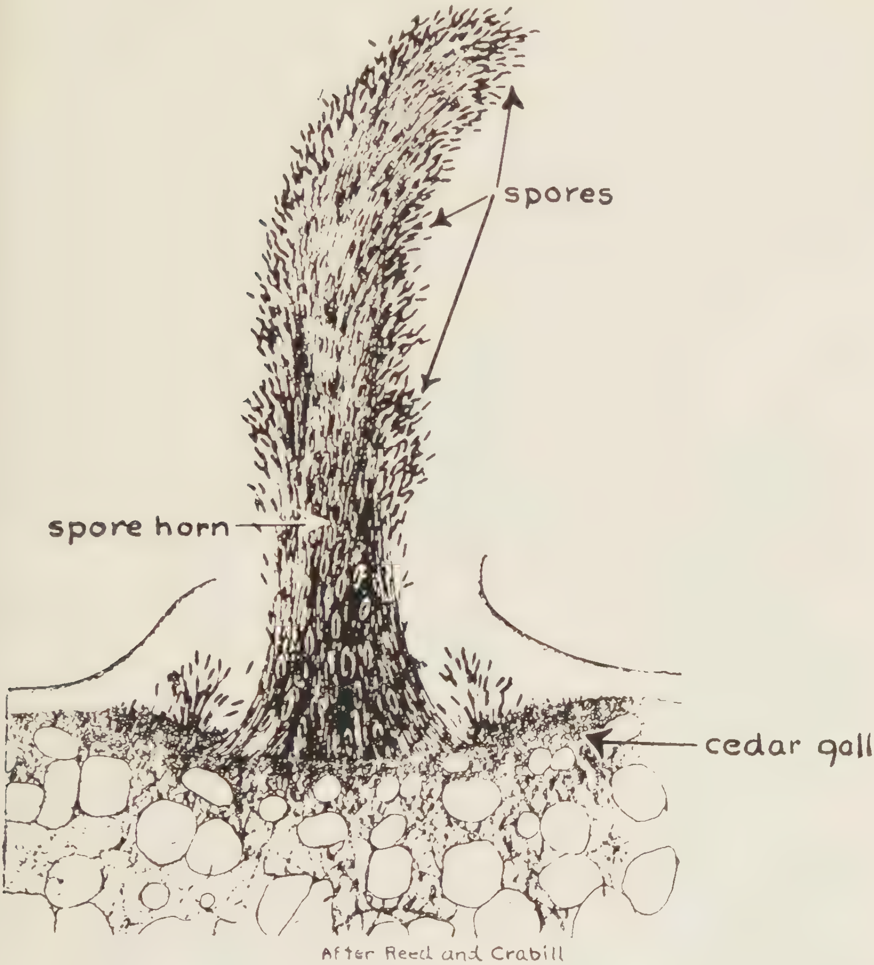


Fig. 31.—Section of Swollen Spore Horn of Cedar Gall.

the disease on the apple, it might be thought that the application of sprays would be effective. Experiments have shown, however, that for various reasons spraying is not practical. The simplest and most effective way to protect the apple crop is to eradicate the red cedar from the immediate neighborhood.

A very common disease of wheat is known as ball smut, stinking smut, or bunt (see Figure 32). When the diseased plant heads, smut balls are produced instead of wheat grains. These smut berries, or balls, are smaller than normal grains and are filled with a fine dark-brown powder. When some of this powder is highly magnified, it is found that

each particle is a spore of the smut fungus (see Figure 33). There are about as many spores in a single smut ball as there are grains in five or six bushels of wheat.

In the process of treshing many of the balls are broken. The loose spores lodge upon the normal grains, to which they adhere, and are thus carried with them when the wheat is planted. The same soil conditions that cause the wheat to sprout also cause the spores to germinate. The germ tube thus produced is the first stage of the smut plant in the soil. This stage never infects a seedling direct but, when it becomes full grown, it gives rise to the secondary spores. From these arise infection threads, which penetrate the shoot of the young wheat seedling and reach the growing point. Here the fungus threads keep pace with the growth of the plant, but give little or no external evidence of their presence until the wheat begins to head. Then the threads grow into the young developing kernels and there begins the formation of the spores which reach maturity about harvest time.

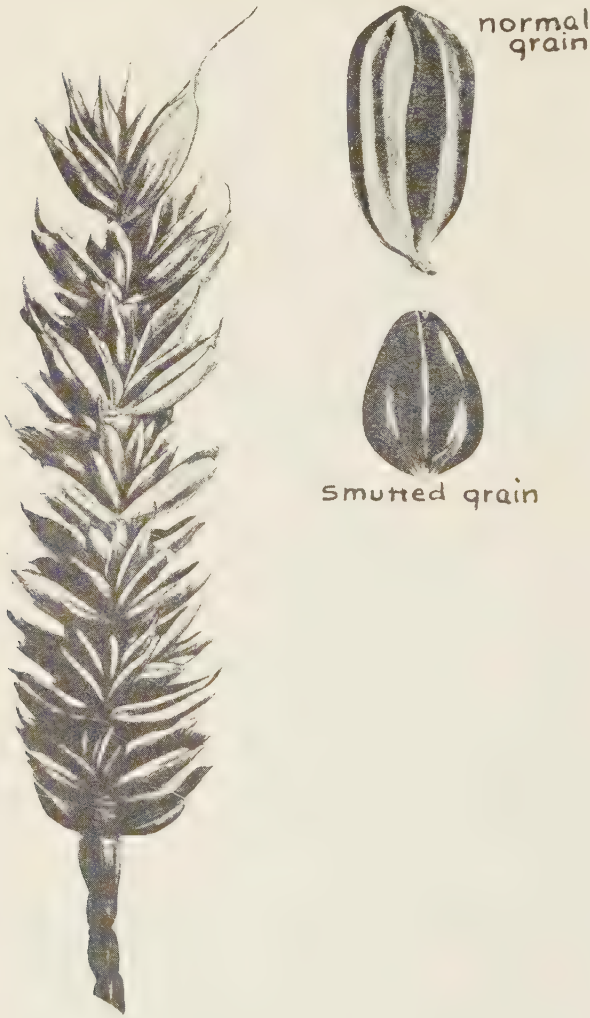


Fig. 32.—Stinking Smut of Wheat.

It is evident that a disease of

this hcaracter cannot be controlled by any external treatment applied to the plant. Measures must be directed, therefore, toward preventing infection by killing the spores on the seed. The wheat is accordingly subjected to the action of certain disinfecting chemicals, or heat, long enough to destroy the spores, but not long enough to injure the grain.

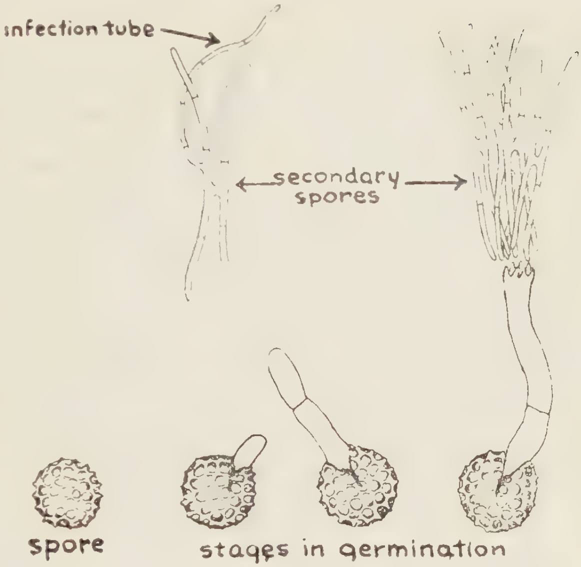


Fig. 33.—Smut Spore Germination.

General Control Measures

It should now be clear that rational methods for plant-disease control, as well as their intelligent application, must be based upon a proper knowledge of the life histories of the causal organisms. Each method has its limitations, however and sometimes a combination of several methods is required to combat the attack of a single fungus. No method can be expected to give perfect control, but any failure to obtain satisfactory results is due to some misapplication of method or material. In following any control measures recommended, the practice of general sanitation should never be disregarded. Since it is seldom possible to cure diseased plants, our efforts are usually directed toward preventing infection. The more common disease-control methods and the principles upon which they are based may be summarized as follows:

Quarantine.—One of the first questions often asked is, "Where did the disease come from?" This often leads to discussion of the spread of plant diseases and injurious insects from one country to another and from place to place in the same country. As a check to the spread of plant diseases we have various quarantine activities. The Federal Plant Quarantine Act of August 20, 1912, empowers the Secretary of Agriculture to prohibit or regulate the entry into this country of foreign plants and plant products that may carry or are infected with new and dangerous pests, either insect enemies or plant diseases. In the accompanying illustration (see Figure 34) inspectors of the Federal Horticultural

Board may be seen at work. The act also empowers the Secretary of Agriculture to establish and maintain quarantined districts within the United States for the purpose of preventing the spread of plant enemies or diseases which may have gained local foothold, and to cooperate with the state in measures looking to the extermination of such pests.

The enforcement of the Federal Plant Quarantine Act has prevented the entry of a very large number of new pests of the farm, orchard, and forest. The number of foreign pests which have been intercepted with plant and plant product importations at various ports of entry makes a list of many thousands, covering a range of hundreds of new pests.

Seed Disinfection.—This method is designed to prevent infection by killing the organisms which rest upon the seed or are carried within them. This is accomplished by heat or certain disinfecting chemicals, such as formaldehyde, corrosive sublimate, copper sulphate, and copper carbonate. Appropriate treatments are applied to such seeds as cotton, watermelon, cucumber, cabbage, and tobacco; to potatoes, sweet potatoes, and certain bulbs; and most of the grains are treated before planting. Figure 35 shows a method of treating seed oats with formaldehyde to prevent smut.

Fig. 34.—Federal Horticultural Board Inspectors at Work.

Fig. 35.—Treating Seed Oats for Smut.

Seed Selection.—This method is employed for two purposes. In seeds, such as beans, corn, and potatoes, certain disease organisms hibernate in such manner that disinfection is not effective. Also, some seeds cannot be treated by any known means without causing considerable injury. In such cases, however, it is often possible to select seed which is free from the organisms and thus avoid infection. Resistant strains can also be secured by seed selection followed by proper plant breeding work. Frequently, seed selection affords only partial control and must be supplemented by other methods. Figure 36 shows inspectors examining a field of potatoes which has been grown for seed. This examination is being made to determine whether the field is sufficiently free from disease to be suitable for seed purposes.

Soil Disinfection.—The object of this method is to destroy certain organisms which are harbored in the soil, and which usually infect the stems, roots, or other underground parts. This method is employed principally in greenhouses, or for limited areas used as plant beds. Heat

Fig. 36.—Selecting Disease-free Potatoes.

and chemicals, such as formaldehyde, are the agents generally used for this purpose. Lime is effective in preventing club root of cabbage and related plants, and inoculated sulphur has rather recently been shown to reduce damage from potato scab, at least under some conditions. Soil treatment must, in some instances be supplemented by other methods in order to be fully effective. A method of disinfecting soil in a tobacco plant bed with steam is shown in the accompanying illustration (see Figure 37).

Application of Fungicidal Sprays.—By this method, disease producing organisms are destroyed by fungicides in the form of dusts or sprays applied to living plants. The accompanying illustration (see Figure 38) shows a method of spraying apple trees with a power sprayer. The most commonly employed fungicides have as their essential constituent either some form of sulphur or copper, usually combined with lime. Combinations of lime and sulphur make the well-known lime sulphur sprays and dusts, while those of lime and copper sulphate produce Bordeaux mixture or Bordeaux dusts.

The application of a fungicide to a plant is generally for the pur-

pose of protecting it from an attack of a fungus. Sometimes, as in the case of the peach leaf-curl, strong fungicides are applied to kill superficial organisms hibernating on the dormant plant. Likewise, in the case of some of the powdery mildews, dusting or spraying is beneficial because of the direct killing action of the fungicide upon the superficial growth of the fungus.

In the great majority of instances, however, fungicides are applied with a view to *covering a healthy plant* which is thus to be kept in a healthy condition; consequently, protective sprays should be given before the attacking organisms are expected to make their appearance. Sprays are usually given at intervals of from ten to fourteen days throughout the danger period in order to meet the needs occasioned by new growth; however, special rules must govern special cases. On a small scale spraying is frequently done with the compressed-air type of sprayer (see Figure 39).

Rain is frequently an important factor to be considered in connection with spraying. Spore production usually takes place most abundantly during rainy weather, and moisture is necessary for spore germination; hence, for effective protection, sprays should be given in ad-

Fig. 37.—Disinfecting Soil in Tobacco Plant Bed with Steam.

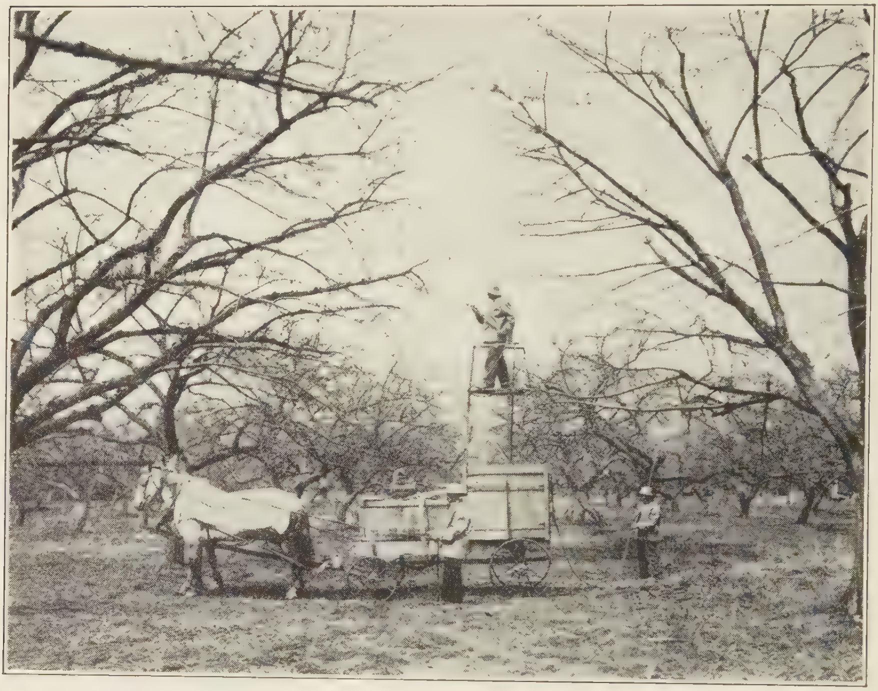


Fig. 38.—Spraying Apple Trees with Power Sprayer.

vance of rainy periods. If the spray has time enough to dry, it is not easily washed off by ordinary rains.

Eradication.—Sometimes the diseased plant may be completely removed, thus eliminating danger of infecting others. This has been successfully done as a means of controlling peach yellows and citrus canker. In other instances, as is in the case with some of the apple cankers, satisfactory control may be obtained by cutting out the diseased part and applying a fungicide. An interesting type of eradication is that involving the removal of alternate or complementary hosts. In some instances, as in the case of apple rust, the red cedar is absolutely essential for the perpetuation of the parasite. In the case of wheat rust the barberry, while not essential for the propagation of the fungus in some sections, oftentimes serves to give the parasite a much wider range of infection. Such complementary host plants should be removed from the vicinity of the crops. The accompanying illustration (see Figure 40) shows a farmer engaged in destroying barberry bushes by the application of salt.

Crop Rotation.—A number of fungus diseases reappear year after year on account of the fact that the soil becomes contaminated with the causal organisms. Constant growth of the same crop in any locality tends to increase the contamination. Suitable rotations prevent many of these diseases from becoming destructive, since they hinder the multiplication of the parasites.

Resistant Varieties.—There is much difference among different varieties in their susceptibility to diseases. In many instances by judicious selection of resistant varieties serious loss may be prevented. Individual plants of the same variety are seldom equally susceptible to disease and advantage has been taken of this to select and breed resistant strains of such crops as cotton, cabbage, watermelon, and tomatoes. This method is at present the best means of controlling some of our most destructive plant diseases. Figure 41 shows the results obtained by selection for resistance to the Fusarium wilt of the tomato. In the row to the left of the center an ordinary commercial strain of the Greater Baltimore variety was planted. Practically all the plants wilted and

Fig. 39.—Spraying Potatoes with a Compressed-air Sprayer.

Fig. 40.—Destroying Barberry by Use of Salt in Effort to Control the Black Stem-rust of Wheat.

died before the fruit was ripened. In the row to the right, a disease-resistant strain selected from the same variety was used. While the soil was just as heavily infested with the wilt fungus, a full crop was obtained.

As crops are grown more intensively on the land the opportunities for damage from plant disease increases. With this increase, however, the knowledge of the causal organisms is constantly growing. Based on this knowledge appropriate control measures, such as quarantine, seed disinfection, seed selection, soil disinfection, application of fungicides, removal of alternate or complementary hosts, crop rotation, and resistant varieties are gradually being worked out with the result that the farmer can continue to produce profitably crops of good quality.

One who understands the true cause and nature of fungous diseases of plants and the principles upon which control measures are based will realize the importance of following carefully and consistently methods recommended. Those interested in the application of specific control measures for diseases of the various crops should refer to special publications of the state agricultural experiment stations and of the United States Department of Agriculture.

Circular No. 269, How to Raise the Community Score by Controlling Insects and Fungous Diseases, and Circular No. 36, Orchard Spraying, have been prepared especially for use in West Virginia and may be obtained upon application to the College of Agriculture at Morgantown. Special publications dealing with the diseases of most common crops may be obtained free of charge from the United States Department of Agriculture, Washington, D. C.

Fig. 41.—Tomato Plants Showing Resistance and Susceptibility to Fusarium Wilt.

Fig. 42.—With a Knowledge of Plant Diseases and the Application of Control Measures Based on Scientific Principles the Farmer Can Produce Profitably Crops of Good Quality.

Circular 42 November, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

FEEDING DAIRY COWS

WEIGHING FEED IS AN IMPORTANT STEP IN SUCCESSFUL FEEDING

By
H. O. HENDERSON and JAMES V. HOPKINS

RULES FOR FEEDING DAIRY COWS

1.--Feed all the roughage that the cows will eat up clean. Legume roughage is best.

2.--Be sure the ration is properly balanced. Then feed the grain mixture in proportion to the milk yield. For the average herd, feed one pound of grain for each 3½ pounds of milk produced. A variety of grains in the mixture is desirable.

3.--Feed some succulent feed such as silage or roots.

4.--During the dry season of the year supplement the pastures by feeding silage or some green crop together with a little grain.

5.--If the cows show a tendency to become fat, reduce the amount of grain or roughage or both.

6.--Give the cows an abundance of pure water.

7.--Feed regularly and give access to salt daily.

FEEDING DAIRY COWS

The average dairy cow in West Virginia produces only 2980 pounds of milk and 160 pounds of butterfat per year, which is entirely too low. This production can be increased best by two methods, first, by the use of better cows, and second, by giving the cows already at hand better feeding and care. While there is no doubt that there is a need for much better cows in the state than are already here, it is true, nevertheless, that if the cows which are already here were fed and cared for more carefully, the production would be greatly increased. The production in many cases could be increased from one-third to one-half with but very little additional cost by following a few simple rules of better feeding. Better feeding methods constitute the quickest and surest way for the West Virginia dairyman to increase the profits from his dairy.

FUNDAMENTALS OF FEEDING

In order for a dairyman to feed intelligently it is necessary for him to understand some of the terms used in feeding dairy cows, and to understand just what feed is made of and how used by the cow.

There is hardly a dairy farmer in West Virginia who has not heard of the terms "protein," "carbohydrates," and "fat," or seen them printed on a tag attached to a bag of feed. But in order to avoid haphazard feeding it is necessary to know the meaning of these terms. In discussing "composition" etc, of feeds it is necessary to make use of the chemical terms, "elements," and "compounds."

Elements constitute the simplest form of any substance known. These substances cannot be separated into simpler ones. For example it would be impossible to obtain anything from a sample of iron (chemically pure) except iron.

Compounds (as referred to in this discussion) are a combination of two or more elements.

Plants. Of the eighty or more known elements only fourteen are commonly present in plants. These elements are rarely found free in nature but are generally found in combination with other elements. Water, protein, carbohydrates, and fats, are the names of important compounds found in plants. Other compounds are also found in the ash (the residue left after burning).

Water is composed of hydrogen and oxygen, and is a constituent of all plants. It makes up a large part of the gross weight of animals, being a part of all bone and flesh.

Protein is a compound found in plants which contain nitrogen in addition to carbon, hydrogen, oxygen, phosphorus, and other elements. It is needed to make blood, muscle, internal organs, skin, hair, and milk. It is the compound which probably most concerns the dairyman since it is the most difficult nutrient to furnish through home grown feeds.

Carbohydrates are compounds of carbon, hydrogen, and oxygen. They furnish energy for carrying on body functions and for keeping the body warm. Carbohydrates are easily supplied through the common farms feeds.

Fat is composed of carbon, hydrogen, and oxygen. It performs the same function in the animal body as carbohydrates but is 2.25 times as efficient.

Total Nutrients. The term "nutrient" is applied to any food constituent or group of food constituents of the same general chemical composition that may aid in the support of animal life. The total nutrients are the total digestible carbohydrates, plus the total digestible protein, plus 2.25 times the total digestible fat.

Feeds. All the feeds commonly fed to dairy cattle come from plants and are composed of the compounds, water, protein, carbohydrates, fat, and ash or mineral matter.

Animal Body. The animal body is composed of the same compounds found in plants or feeds. It is, therefore, necessary to feed the right kinds and amounts of feed in order to maintain the animal body.

Milk. Milk also contains the same compounds (in different forms) found in feeds and in the body. So it is not only necessary to furnish enough feeds for body maintainance, but also such feeds as contain the right amounts of protein, carbohydrates, fat, and mineral matter must be supplied for milk production.

The accompanying chart shows how the elements unite into compounds which form the feed out of which animals manufacture milk and secure their body needs (Figure 1).

FROM ELEMENTS TO MILK

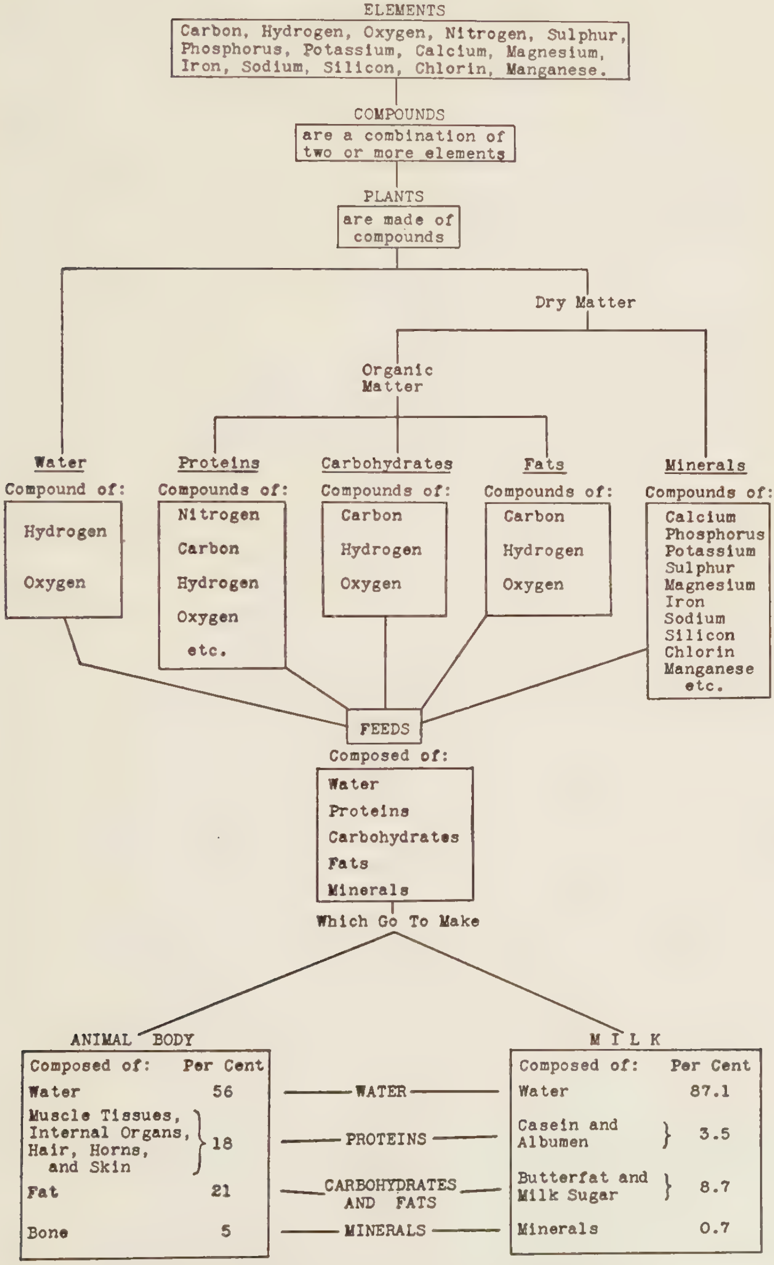


Fig. 1.--Chart showing interrelation of Plant and Animal Life and the common component elements with their occurrence in various substances which go to make up feeds and finally milk.

(Figure 1) shows that the dairy cow produces her milk entirely from the feed and water which she consumes. The feed is composed of water, protein, carbohydrates, fat, and mineral matter. Likewise the milk is composed of exactly the same constituents. The dairy cow also needs exactly the same food for her maintenance, that is, to keep her body in running order, pumping blood, chewing and digesting food, and making body repair. The dairy cow must have this food for maintenance before she will use any of it for milk production. The accompanying diagram (Figure 2) illustrates how the feed fed to the dairy cow is utilized.

WHAT BECOMES OF A COW'S FEED

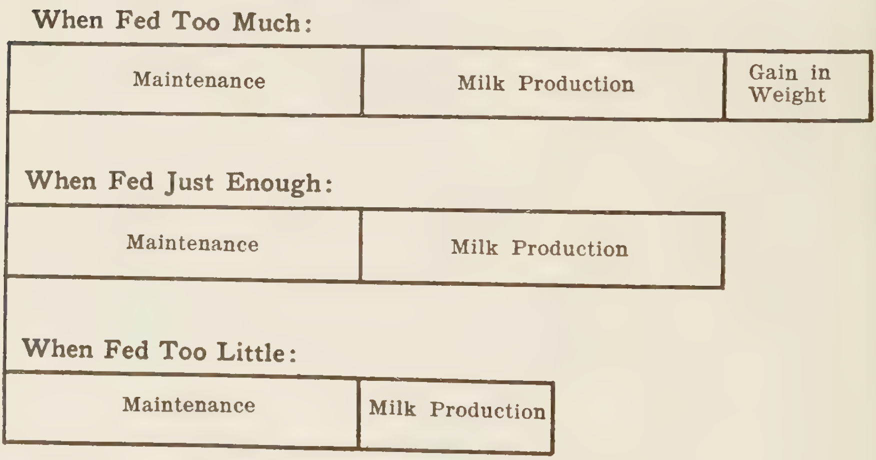


Fig. 2.--Chart showing how the dairy cow utilizes her feed.

It will be noted from a study of the diagram shown in Figure 2 that a cow when fed too much uses the excess feed to put on weight, when she is fed just enough she produces the maximum amount of milk with no waste, and when she is fed too little, she loses first in milk, and later in weight, both of which are decidedly unprofitable to the owner.

SOME COMMON FEEDS

Before it is possible to feed the dairy cow most efficiently, it is necessary to know the characteristics of some of the more important dairy feeds. It is always best to feed as many home-grown feeds as possible and to buy only what may be necessary to balance them properly. In the following paragraphs are given some of the characteristics of the more important dairy feeds used in West Virginia.

Legume Roughages

Alfalfa. Alfalfa hay is one of the very best roughages for dairy cattle. It is very palatable and has a good effect upon the digestive system as it is slightly laxative in character. It is high in protein, and is the highest of all the common feeds in calcium.

Clover. Clover hay has the same advantages as does alfalfa hay, except that it is a little lower in protein and is slightly less palatable. Alsike, Crimson, and Red Clover have about the same feeding value, but Alsike is finer in the stem, which makes it especially well adapted for feeding young calves.

Soybeans. Soybean hay is fast becoming one of the most valuable crops raised by West Virgina dairymen. When properly cured, it makes one of the very best roughages for dairy cattle. It is slightly higher in protein and total digestible nutrients than is alfalfa. It is very palatable, but when allowed to get too ripe, has coarse, woody stems which the cows will refuse. It is very slightly constipating in its effect, but is very high in calcium.

Non-Legume Roughages

Timothy Hay. Timothy hay is very low in protein and is not palatable except when harvested early. It is constipating in effect and low in its mineral content. Cows do much better when fed one of the legume hays than when fed timothy.

Corn Stover. Corn stover (ears taken off) or "fodder," as it is incorrectly called, is one of the lowest protein roughages. It is not palatable, is constipating, and is low in minerals. It should be fed only in small quantities to dairy cows. Its feeding value is not improved by shredding.

Straws. Straw is a very poor feed for dairy cows, especially if the plant is allowed to become dead ripe. Oats straw is a little better than wheat straw or rye straw. All straws are low in protein and minerals, unpalatable, and constipating.

Silages. Corn silage is one of the cheapest and best roughages for dairy cows and is especially valuable because it offers the best means of supplying the necessary succulence during the winter. It is very palatable, and is laxative in its effect. Sunflower silage has been gaining in importance during the last few years. It is not as palatable as is corn silage and does not seem to give quite as good results, although the yield

is considerably greater which makes it particularly adapted to regions unadapted to corn or of limited tillable acreage.

Roots. Mangels, rutabagas, sugar beets, and turnips are fed to cows with good results. They are succulent in nature, laxative, and very palatable. The mangel is the most widely used and is unexcelled in adding succulence to the ration. It should be fed more generally, especially where there are too few animals to justify a silo or where the tillable acreage is limited.

Concentrates

Corn. Corn is grown on most West Virginia farms and should usually be included in the dairy ration. Cows like it and it supplies a large amount of total nutrients economically. It is low in protein and also in minerals, therefore, some high protein feed must be used in order to supply these deficiencies. It is best to feed corn ground as a meal. Sometimes whole ears are ground making *corn and cob meal.* While cows do not like corn and cob meal quite as well as corn meal, it is often used to give bulk to the ration.

Oats. Oats is an excellent feed for dairy cattle and when not too high in price should be used in the ration. They are considerably higher in food value than wheat bran. They are bulky, palatable, fairly high in protein and mineral matter, and if home-grown the straw comes in handy for bedding.

Barley. Barley is an excellent substitute for corn. It can be substituted for corn pound for pound, with equally good results. It contains a little more protein than corn but is a little lower in total digestible nutrients.

Buckwheat. Because the large amount of fibre in the buckwheat hull, the whole grain is not so desirable for dairy cows as are the buckwheat middlings or bran of this grain. *Buckwheat middlings* are higher than wheat bran in feeding value and prove a very satisfactory feed for dairy cows.

Wheat Bran. Wheat bran is an excellent dairy feed. It is bulky and acts as a mild laxative. It also has a cooling effect which makes it very useful as a feed for cows after calving. It is the highest of the common feeds in its phosphorus content. *Wheat middlings* or "shorts" is a very satisfactory feed for dairy cows, but is more like corn in composition and properties than bran. Middlings, if they can be purchased cheaper than corn, may be used as a substitute for corn in the ration.

Gluten Feed and Gluten Meal. Gluten meal is high in feeding value but is heavy and not very palatable. It should always be fed in a mixture with other feeds. It is a by-product of starch and glucose manufacture. When it is mixed with corn bran, it is known as *Gluten feed* which is now largely used as a dairy feed. It is often a cheap source of protein.

Cottonseed Meal. Cottonseed meal furnishes protein in the largest quantity and usually is the cheapest form of any of the common feeds. It is also high in minerals. It is somewhat constipating, however, and not very palatable, hence, it should always be fed in combination with other feeds which will overcome these faults. It should never be fed in larger amounts than three or four pounds per day. Sometimes cottonseed hulls are ground and mixed with the meal and sold as cottonseed feed. This is considerably lower in feeding value than the meal.

Linseed Oil Meal. Linseed meal contains a high per cent of protein and is a very valuable feed. It is laxative, very palatable, and it has an excellent physiological effect on the digestive system of the cow. Because of these factors it is especially good when no succulent feed is being used. It gives best results when fed with other grains and not in too large quantities. It is the residue after linseed oil is extracted from flax seed.

Peanut Meal. Peanut meal is becoming more important as a dairy feed. It is a by-product from the manufacture of peanut oil. It varies considerably in composition, but high grade peanut meal is very high in protein, is palatable and has a slightly laxative effect upon the cow.

Dried Beet Pulp. Dried beet pulp is very high in carbohydrates, but low in protein. When silage or other succulent feeds are not available, dried beet pulp makes an excellent substitute when soaked with water for about twelve hours before feeding. It is very palatable, and has a very good physiological effect upon the cow.

Molasses. Molasses is not usually fed for its food value, as it contains practically no protein; and for its total nuterients it is not an economical feed. Its chief valve is as an appetizer for when sprinkled over unpalatable feeds it lends palatability to them. Molasses is quite laxative and cannot be fed in large quantities. It is often used when cows are on official test in order to have the cows consume more feed.

Ready Mixed Feeds

There are a large number of ready-mixed dairy feeds now being sold in West Virginia. They have the advantage of supplying the necessary variety to a ration and being ready mixed they save the labor of mixing. In the past, these ready-mixed feeds were not looked upon with favor because many of them were sold simply as a means of disposing of some inferior products. More recently laws have been passed requiring the labeling of each sack with a guaranteed analyses. At the present time many excellent ready-mixed feeds are to be found on the market. Still more recently, the *open formula* feed has been put on the market. These open formula feeds have the advantage that they show on the sacks the feeds and the amount of each which has been used in the ration. They have been gaining in popularity very rapidly.

Ready-mixed feeds are of special value to the dairyman who uses only a small amount of feed or who is so located that it is impossible to secure readily a variety of feeds for home mixing. The buyer should always pay close attention to the guaranteed analyses, so that he may get his protein and total nutrients as cheaply as possible. His decision as to the use of ready-mixed feeds should depend largely upon the relative price. If the dairyman, however, has on his farm corn, barley, or oats, and needs a high protein feed to balance these, he as a rule can purchase his protein cheaper in the form of cottonseed meal, linseed meal, or gluten feed. It is always best to figure the cost of a pound of protein from each before purchasing, and in that way be sure of purchasing the most economical ration.

DESIRABLE CHARACTERISTICS OF A RATION

In the making of a dairy ration it should be the aim as nearly as possible to imitate early summer pasture conditions. Every dairyman knows that the period of highest and most economical milk production is during the early summer months. The reason for this is not hard to ascertain. Early summer pasture provides for the dairy cow an *abundance* of *palatable* feed which is *succulent* in nature. It also has plenty of *bulk* and *variety* and it has a *good physiological effect* upon the cow. Pasture also is *cheap*. These characteristics of pasture are the things which a good feeder tries to imitate throughout the year.

Abundance of Feed. An abundance of feed is the first essential in feeding cows for profit. The cow should be looked upon simply as a factory, and as in any other factory, the cheapest production is possible only when the plant is being run nearly to its full capacity. The most common mistake in feeding dairy cows is the failure to give enough feed

to make full use of the milk producing ability of the cows. Cows should be fed as individuals, that is, in proportion to the milk which they are producing. There is no profit in a herd of half-starved cows.

Palatable Feed. A feed to be palatable must be pleasing in flavor so that cows like it. A cow will do her best when she relishes her feed. A ration may contain everything necessary for maximum production and if it is not palatable, the cow may not consume enough of it for her maximum production. We want to tempt the cow's appetite and induce her to eat feed up to the limit of her ability for production. Early spring pasture is a very palatable feed. Pasture in late summer is much less palatable, which is one reason why the cows drop off so rapidly at that time.

Succulent Feed. A succulent feed is one which contains the juices of green forages similar to the natural juices of pasture grass. These juices stimulate the production of milk and a maximum flow of milk is difficult without them.

Bulk. Pasture is bulky. Likewise any good ration should be bulky to enable the digestive juices to penetrate the food most completely and thereby facilitate digestion.

Variety. It is well to add variety to a ration. If the feed is obtained from only one plant, some of the essentials for maximum milk production may be omitted. It is well to have two, or better three, different plants represented in the grain ration. This will help furnish the special forms of protein required by a cow in milk and also the needed mineral matter. Variety is especially important when large records are being attempted.

Physiological Effect. Each feed has its own specific effect upon the cow's body. The effects of certain feeds are very pronounced. The bowels of the dairy cow should be in slightly laxative condition if she is to make her best production. Fresh pasture is laxative in nature. When roughages are constipating in effect, the grain ration should be of a laxative nature.

Cheap. Good pasture not only is a good feed but it is a cheap feed. The careful feeder will also try to select cheap feeds but in this he will not make the cost price per ton the essential consideration. The important thing which should be considered is the cost of one pound of protein or one pound of total nutrients.

BALANCING RATIONS FOR A DAIRY HERD

A balanced ration is one that exactly meets the daily needs of a dairy cow, both for the maintenance of her body and for the production of milk. Feeds are divided into two general groups: roughages and concentrates. Roughages are the cheaper, and so cows should be fed all that they will clean up. They usually, however, cannot eat enough roughage to supply the required food nutrients for both maintenance and milk production. They must, therefore, be fed grain in addition to the roughage. The concentrates are used to balance the roughage fed; hence the kind of concentrates or grain mixture needed will depend upon the class of roughage fed. The different kinds of roughage fall into three general classes based on their protein content.

The groups of roughages and the percentage of protein in the grain mixture to feed with them are as follows:

1. **Low Protein Group.** Timothy hay, corn stover, straw, corn silage, or any other non-legume. Percentage of digestible protein required in grain mixture--**18** to **22**.

2. **Medium Protein Group--**Mixed hay, clover and silage, or other roughages, with at least half of the roughage legume. Percentage of digestible protein required in grain mixture--**15** to **18.**

3. **High Protein Group--**Clover hay, alfalfa hay, soybean hay, or any of the legume roughages. Percentage of digestible protein required in grain mixture--12 to 15.

It is well to understand that digestible protein is the protein available for the use of the animal and should be distinguished from crude protein which is represented by the figures printed on the sacks of the various feeds. Crude protein content runs from one to six per cent higher than does digestible protein.

Practice in Making Grain Mixtures

For general farm use, it is not always practical to balance exactly the amounts of protein, fats, and carbohydrates needed. Since there is seldom a deficiency in carbohydrates and fats, when the cow has all the roughage that she can eat, a roughly balanced ration may be obtained by balancing the protein of the grain mixture to go with the kind of roughage as already indicated under the three groups of roughages and disregarding the carbohydrates and fat.

As an example of this method of making up a ration for a dairy

herd let us assume that we have on hand alfalfa hay and corn silage for roughage, which is the medium protein group, and that we have available corn meal, ground oats, wheat bran, and cottonseed meal. By referring to Table 2 we get the following figures for protein:

100 pounds cornmeal contains	7.1 pounds digestible protein.
100 pounds wheat bran contains	12.5 pounds digestible protein.
100 pounds ground oats contains	9.7 pounds digestible protein.
100 pounds cottonseed meal contains	37.0 pounds digestible protein.
400 pounds of the mixture contains	66.3 pounds digestible protein.

66.3 divided by 400 equals .166 or 16.6 per cent digestible protein.

By referring to the Groups of Roughages, it will be noted that when the roughage is in the medium protein group, the percentage of protein in the grain mixture should be from 15 to 18 per cent. This ration, then, should fulfill the needs, provided of course, it fulfills the requirements as to bulk, variety, palatability, physiological effect, mineral content, etc. This ration should fulfill these requirements.

Now let us assume that instead of alfalfa and silage for roughage we have only timothy hay and corn stover, which are in the low protein group, with the same concentrates as before. It would be necessary then to add more of the high protein feeds as follows:

400 pounds of the mixture contains	66.3 pounds digestible protein
100 pounds of the cottonseed meal contains	37.0 pounds digestible protein
500 pounds of the new mixture contains	103.3 pounds digestible protein

103.3 divided by 500 equals .2066 or 20.6 per cent digestible protein.

By referring to the Groups of Roughages, it will be noted that when the roughage is in the low protein group the digestible protein in the grain mixture should be from 18 to 22 per cent. This ration fills these requirements and therefore should be a good ration under the given conditions.

Now suppose that the roughage consisted of alfalfa hay which is in the high protein roughage group, and that the same concentrates were available. It would be necessary to add a low protein concentrate such as corn as follows:

400 pounds of the mixture contains	66.3 pounds digestible protein.
100 pounds corn meal contains	7.1 pounds digestible protein.
500 pounds of the new mixture contains	73.4 pounds digestible protein.

73.4 divided by 500 equals .147, or 14.7 per cent digestible protein.

We note that the grain mixture in the high protein group should be between 12 and 15 per cent and hence the above ration would fill the

requirements but could be still a little lower in protein, if desirable for any reason.

Any of the foregoing rations would be suitable for the conditions given, provided they were fed in proportion to the amount of milk that the cows produced; that is, one pound of grain to each three or four pounds of milk that the cow produces, as pointed out in the general rules for feeding dairy cows on page 2.

It is comparatively easy to balance a grain mixture in this way for any kind of roughage. If the roughage is low grade, use a higher protein percentage in the grain mixture and vice versa. It is important, however, to keep in mind the characteristics of the feeds when making up the grain ration and always to feed the ration according to production.

It is also well to consider the cost of the protein in the feeds used to make up the ration and always to take the cheapest, everything else being equal. This can easily be ascertained by the use of the cost co-efficients for getting cost of digestible protein and total nutrients as given in Table 2.

Substitutions

If one has a ration already worked out for his herd, it is very handy sometimes to make certain substitutions.

In a ration, any of the following feeds can be interchanged as indicated without seriously affecting the food value of the ration:

1. Oats for wheat bran and vice versa.
2. Ground barley for corn meal and vice versa.
3. Corn and cob meal for corn meal and vice versa.
4. Hominy for corn meal and vice versa.
5. Cocoanut meal for gluten feed and vice versa.
6. Buckwheat middlings for gluten feed and vice versa.
7. Linseed oil meal for cottonseed meal and vice versa.

Good Grain Mixtures with Different Roughages

A series of grain mixtures suitable to West Virginia conditions are given here for convenience.

For Low Protein Roughages

(Digestible protein in grain mixture 18 to 22 per cent.)

No. 1. Digestible Protein 18.9%

200 pounds wheat middlings
100 pounds corn and cob meal
100 pounds cottonseed meal
50 pounds linseed meal

No. 2. Digestible Protein 20%

100 pounds corn meal
100 pounds cottonseed meal
100 pounds linseed meal
200 pounds wheat bran

No. 3. Digestible Protein 20.6%

100 pounds corn meal
100 pounds cottonseed meal
100 pounds gluten feed
50 pounds wheat bran

No. 4. Digestible Protein 20.5%

400 pounds ground barley
400 pounds gluten feed
400 pounds cottonseed meal
100 pounds linseed meal

No. 5. Digestible Protein 19.1%

100 pounds corn-and-cob meal
100 pounds ground oats
200 pounds cottonseed meal
200 pounds wheat bran

For Medium Protein Roughages

(Digestible protein in grain mixture 15 to 18 per cent.)

No. 6. Digestible Protein 15.0%

100 pounds corn meal
100 pounds wheat bran
100 pounds ground oats
100 pounds linseed meal

No. 7. Digestible Protein 17.3%

300 pounds corn meal
100 pounds cottonseed meal
200 pounds buckwheat middlings
100 pounds wheat bran

No. 8. Digestible Protein 16.8%

200 pounds corn meal
150 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 9. Digestible Protein 16.3%

100 pounds corn-and-cob meal
100 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 10. Digestible Protein 15.7%

200 pounds ground corn
200 pounds ground oats
200 pounds wheat bran
400 pounds linseed meal

For High Protein Roughages

(Digestible protein in grain mixture 12 to 15 per cent.)

No. 11. Digestible Protein 12.3%

200 pounds corn meal
100 pounds ground oats
100 pounds wheat bran
100 pounds buckwheat middlings

No. 12. Digestible Protein 12.2%

200 pounds corn meal
100 pounds gluten meal
100 pounds wheat bran

No. 13. Digestible Protein 13.3%

200 pounds corn meal
100 pounds ground oats
100 pounds wheat bran
100 pounds linseed meal

No. 14. Digestible Protein 14.1%

400 pounds corn meal
100 pounds cottonseed meal
100 pounds wheat bran
100 pounds gluten feed

No. 15. Digestible Protein 14.4%

300 pound ground corn
100 pounds wheat bran
100 pounds cottonseed meal

Balancing Rations Accurately

Sometimes it is desirable to balance a ration for a herd or for an individual cow more accurately than the protein requirement gives it. Table 1 gives the daily requirements for dairy cows according to the Morrison Feeding Standard, using the average of the extremes in the requirements for milk production.

Table 1. Daily Requirements for Dairy Cows

Maintenance and Production	Digestible Crude Protein in Pounds	Total Digestible Nutrients in Pounds
Maintenance for 1000-pound cow	0.700	7.925
Maintenance for each 100 pounds live weight	0.070	0.7925
For 1 pound of 3 per cent milk	0.052	0.271
For 1 pound of 3.5 per cent milk	0.055	0.300
For 1 pound of 4 per cent milk	0.059	0.328
For 1 pound of 4.5 per cent milk	0.063	0.357
For 1 pound of 5 per cent milk	0.066	0.382
For 1 pound of 5.5 per cent milk	0.070	0.406
For 1 pound of 6 per cent milk	0.074	0.431

It will be seen by referring to Table 1 that a 1250 pound cow will require for maintenance 0.875 pounds of digestible protein and 9.906 pounds of total digestible nutrients. However, if this cow is producing 24 pounds of 3.5% milk, she will require in addition, according to the table, 1.32 pounds of digestible protein and 7.20 pounds of total digestible nutrients. Her total requirements, therefore, would be 2.195 pounds of digestible protein and 17.106 pounds of total digestible nutrients, which total we get by adding together the maintenance requirement and the milk requirement, thus:

Maintenance and Production	Digestible Crude Protein in Pounds	Total Digestible Nutrients in Pounds
Maintenence for 1250-pound cow	0.875	9.906
Production of 24 pounds of 3.5 milk	1.320	7.200
Total requirements	2.195	17.106

Having found out exactly what it takes to maintain a cow of this size, giving the quantity of milk mentioned, the problem then is how to select the right feeds in the correct proportion in order to meet these requirements.

The following ration very closely gives the total requirements:

Feeds	Total Crude Protein in Pounds	Total Digestible Nutrients in Pounds
10 pounds alfalfa hay	1.060	5.160
35 pounds corn silage	0.385	6.195
5 pounds corn meal	0.355	4.085
2 pounds ground oats	0.194	1.408
½ pound cottonseed meal	0.185	0.391
Total	2.179	17.239

By the same method a ration for any cow can be worked out when her requirements based on her approximate weight, her milk production, and percentage of butterfat are known. The average requirements of a herd can also be used in computing a ration for a herd as a whole.

Feeding Cows On Pasture

The problem of feeding cows on pasture is one that is frequently overlooked by dairymen. The beginning of the pasture is awaited with impatience by many dairymen. Often this impatience overcomes good judgment and the cows are turned on pasture too early in the spring. When this is done it generally decreases the yield of grass throughout the rest of the summer. Since much of the food of the grass plant is manufactured in the leaves or blades, if the cows are allowed to graze while the grass is very short, its growth will be slow. The early grasses are mostly water and heavy milking cows cannot eat enough immature grass to supply them with the necessary nutrients. Hence it is a good practice to continue feeding the cows some hay, silage, and grain for a time after they are turned on pasture.

Experience has proved that even good pasture will not furnish enough food for the high producing cow. Grasses contain a large amount of water and are bulky which makes it impossible for heavy producers to consume enough to keep up production.

The best abundant pasture, will furnish only enough nutrients for cows which are producing not more than 20 pounds of milk per day. A guide for feeding grain to cows on pasture is as follows:

For Jersey or Guernsey Cows Producing

25 pounds of milk daily	feed 1 pound of grain to each 6	pounds of milk
30 pounds of milk daily	feed 1 pound of grain to each 5	pounds of milk
35 pounds of milk daily	feed 1 pound of grain to each 4½	pounds of milk
40 pounds of milk daily	feed 1 pound of grain to each 4	pounds of milk

For Holstein Ayrshire, Brown Swiss, or Shorthorn Cows Producing

25 pounds of milk daily	feed 1 pound of grain to each 7	pounds of milk
30 pounds of milk daily	feed 1 pound of grain to each 6	pounds of milk
35 pounds of milk daily	feed 1 pound of grain to each 5½	pounds of milk
40 pounds of milk daily	feed 1 pound of grain to each 4	pounds of milk

In feeding grain to cows on abundant pasture the grain mixture can be made up of relatively small amounts of the high protein concentrates. The following grain mixtures have proved to be satisfactory.

No. 1. Digestible Protein 12.7%

100 pounds corn meal
100 pounds wheat bran
25 pounds cottonseed meal

No. 2. Digestible Protein 11.3%

400 pounds corn meal
100 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 3. Digestible Protein 10.4%

100 pounds wheat bran
100 pounds ground oats
50 pounds corn meal

As late summer approaches the need for pasture supplement generally becomes more acute and the grain mixture at this time should be richer in protein. It is during this period that the pastures generally become short due to dry weather. Silage has proved to be the best forage supplement for pasture, although soiling corps such as green corn, oats, or soybeans may be used if the land and labor are available. It pays to supplement these feeds with one of the above grain mixtures and hay, if necessary, in order to keep up the production of heavy milking cows.

OTHER CONSIDERATIONS

Common Salt. It has always been known that cattle have a craving for common salt and that to deprive them of this substance will end in disastrous results. They will gradually lose vitality, their hair will become rough, they will become thin in flesh and finally will have a complete breakdown. It is necessary, therefore, to supply dairy cattle with plenty of salt.

One of the most common ways of supplying the needed salt is to keep it so the animals will have free access to it and will take what they require. It may be supplied also by mixing it with the grain ration in the proportion of 1 to 1¼ pounds of salt for each 100 pounds of grain mixture. The cows should also be given free access to salt so that they may be supplied with additional salt which may be required. The practice of salting only at intervals of certain periods is not to be recommended. The amount actually needed is about ¾ of an ounce daily for each 100 pounds of live weight and ½ ounce in addition for each 20 pounds of milk produced.

Calcium and Phosphorus. The importance of calcium and phosphorus in the dairy ration has recently been given much publicity, but their importance has been somewhat over estimated. Under West Virginia conditions, if the dairy cows are given plenty of legume hay in winter and pasture in summer, and are fed a good grain ration, there is little to be feared from lack of these elements. Legume hays are the best source of calcium while concentrates such as wheat bran and cottonseed meal, are the best sources of phosphorus.

If, however, cows show abnormal appetites such as a craving for wood, bones or dirt, there is a strong indication that the ration is lacking in one or both of these elements. This is more liable to be true with the heavy producing cows or when the roughage is timothy or other non-legume hay. In either of these cases it is usually advisable to supply some of these elements, for while the cow may not show any definite signs nevertheless she is no doubt drawing upon her body reserve which must later be replenished.

When it is found advisable to supply these elements in some form other than that supplied by the feeds being used, it is usually recommended to feed some bone meal, of the kind especially prepared for livestock feeding. This contains both calcium and phosporus in the proportions used in the body. It is sold by the large packing houses under the name of "raw bonemeal for feeding." Spent bone black serves the same purpose as the bone meal and sometimes can be purchased at a lower price. Ground limestone or wood ashes may also be used but they supply only the calcium. In case ground limestone is used, only limestone which is low in magnesium should be used.

Many commercial mineral compounds are on the market but no better results can be expected from them than from bone meal or a mixture of bone meal and limestone. The price of commercial preparations is usually much higher than that of the bone meal.

The bone meal, ground limestone, or wood ashes can be fed like salt by allowing free access to it, or it may be added to the grain ration at the rate of about 2 pounds to each 100 pounds of the ration.

Water. Since milk is 87 per cent water, it is obvious that dairy cows should receive all the water that they can drink. A large cow milking heavily will drink as much as 100 pounds (8 to 10 gallons) of water in a day. When closely stabled cows should be watered at least twice a day, or better still, have water where they can get it when they want it. In cold weather the water ought to be at least 20 degrees above freezing.

Table 2. Average Amount Digestible Protein and Total Nutrients in 100 Pounds of Common Feeds (Analyses Henry and Morrison "Feeds and Feeding," 18th Edition).

Feeds	Pounds Digestible Crude Protein	Pounds Total Digestible Nutrients	Cost Coefficient ①	
			Protein	Total Nutrients
GRAINS				
Corn	7.5	85.7	13.33	1.166
Cornmeal	7.1	81.7	14.08	1.224
Corn-and-cob meal	6.1	78.1	16.39	1.280
Oats	9.7	70.4	10.31	1.424
Barley	9.0	79.4	11.11	1.259
Buckwheat	8.1	63.4	12.34	1.574
Soybeans	33.2	94.1	3.01	1.061
Cowpeas	19.4	76.4	5.15	1.309
Rye	9.9	81.0	10.10	1.234
BY-PRODUCTS				
Cottonseed meal (choice)	37.0	78.2	2.70	1.278
Cottonseed meal (prime)	33.4	75.5	2.99	1.324
Linseed meal (old process)	30.2	77.9	3.31	1.284
Linseed meal (new process)	31.7	75.9	3.15	1.317
Gluten feed	21.6	80.7	4.63	1.238
Gluten meal	30.2	84.0	3.31	1.190
Wheat bran	12.5	60.9	8.00	1.642
Wheat middlings	13.4	69.3	7.46	1.443
Wheat middlings (flour)	15.7	78.2	6.37	1.278
Buckwheat middlings	24.6	76.6	4.07	1.305
Corn bran	5.8	73.1	17.24	1.368
Hominy feed	7.0	84.6	14.29	1.182
Cocoanut meal (old process)	18.6	78.8	5.32	1.269
Soybean oil meal	39.7	84.5	2.51	1.183
Sugarbeet pulp (dried)	4.6	71.6	21.74	1.396
Distillers grain from corn (dried)	22.4	88.9	4.46	1.124
Malt Sprouts	20.3	70.6	4.92	1.416
Molasses (beet)	2.9	58.7	34.48	1.703
Molasses (cane)	1.0	59.5	100.00	1.681
Alfalfa meal	10.2	50.7	9.80	1.972
DRIED ROUGHAGES				
Alfalfa hay	10.6	51.6	9.43	1.938
Soybean hay	11.7	53.6	8.55	1.865
Clover (red)	7.6	50.9	13.16	1.964
Clover (alsike)	7.9	47.3	12.67	2.114
Clover (crimson)	9.7	48.7	10.31	2.053
Clover (sweet)	10.0	47.0	10.00	2.149
Cowpeas	13.1	49.0	7.63	2.041
Mixed timothy and clover	4.0	46.2	25.00	2.164
Timothy	3.0	48.5	33.33	2.061

①To get the cost of Protein and Total Nutrients in feeds multiply the cost coefficient by the cost per hundred pounds of feed.

Table 2. (Continued)

Feeds	Pounds Digestible Crude Protein	Pounds Total Digestible Nutrients	Cost Coefficient	
			Protein	Total Nutrients
Corn fodder medium in water (ears included)	3.0	53.7	33.33	1,866
Corn stover (ears removed)	2.2	52.2	45.45	1.911
Millet (Hungarian)	5 0	55.0	20.00	1.818
Oat hay	4.5	46.4	22.22	2.155
Oat straw	1.0	45.6	100.00	2.193
Buckwheat straw	4.2	33.2	23.81	3.012
Wheat straw	0.7	36.9	142.86	2.172
SILAGE AND ROOTS				
Corn silage (matured)	1.1	17.7	90.00	5.649
Sunflower silage	1.0	12.6	100.00	7.936
Clover silage	2.0	13.4	50.00	7.462
Soybean silage	2.8	15.6	35.71	6.410
Beets (common)	0.9	10.2	111.11	9.803
Beets (sugar)	1.2	14.0	83.83	7.142
Turnips	1.0	7.4	100.00	13.513
Mangels	0.8	7.4	125.00	13.513
Pumpkins (field)	1.1	6.7	99.99	14.924
Rutabagas	1.0	9.4	100.00	10.637

Circular 43

December, 1926

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

Producing Cream on the Farm

A TYPICAL WEST VIRGINIA DAIRY FARM

By

JAMES V. HOPKINS and G. MALCOLM TROUT

Rules for Producing Good Cream

1.—Keep the milk, cows, and stable clean.

2.—Milk with clean dry hands.

3.—Use a small top or covered milk pail.

4.—Remove milk immediately from barn and separate.

5.—Adjust cream screw on separator so as to get a 30 to 40 per cent cream.

6.—Cool cream promptly by setting in cold water and stirring frequently.

7.—Wash, rinse, scald, dry, sun, and air all dairy utensils.

8.—Sterilize strainer after each use by pouring scalding water over it.

9.—Keep cows off pastures infected with onions, garlic, and other weeds, the flavors of which are carried through into the milk.

10.—Do not allow cream to freeze.

11.—Deliver the cream three times a week in summer and twice a week in winter.

12.—Protect cans from exposure to sun during delivery by wrapping with a wet sack or blanket.

PRODUCING CREAM ON THE FARM

The point has been reached in West Virginia's dairy development where large amounts of cream are being shipped to creameries instead of being converted into butter. In addition several million pounds of farm butter are made annually in districts remote from better transportation facilities. Much of this butter has a very low score, due, largely, to the fact that the cream from which it was made was of inferior quality.

The quality of cream determines the quality of butter made therefrom and hence the price obtained. The difference in price between butter scoring 87 points and butter scoring 92 points is but a few cents, but when this difference in price is applied to eighteen million pounds of butter, the aggregate amounts to many thousands of dollars.

Just as undesirable qualities would appear in butter made on the farm from inferior cream, so would they appear in the butter were the cream delivered to a creamery and handled by a proficient butter maker. The farmer controls the quality and hence the price. Many creameries to-day are buying on the quality basis, and paying a premium for sweet, clean-flavored cream.

One can overcome the loss encountered in selling a poor quality product by exercising care in the production and handling of milk and cream, realizing that good butter, such as might be sold in cartons bearing the "Mountain State Brand," can be made only from clean, high quality cream.

Cream Production

The essential steps in the production and marketing of first grade cream are:

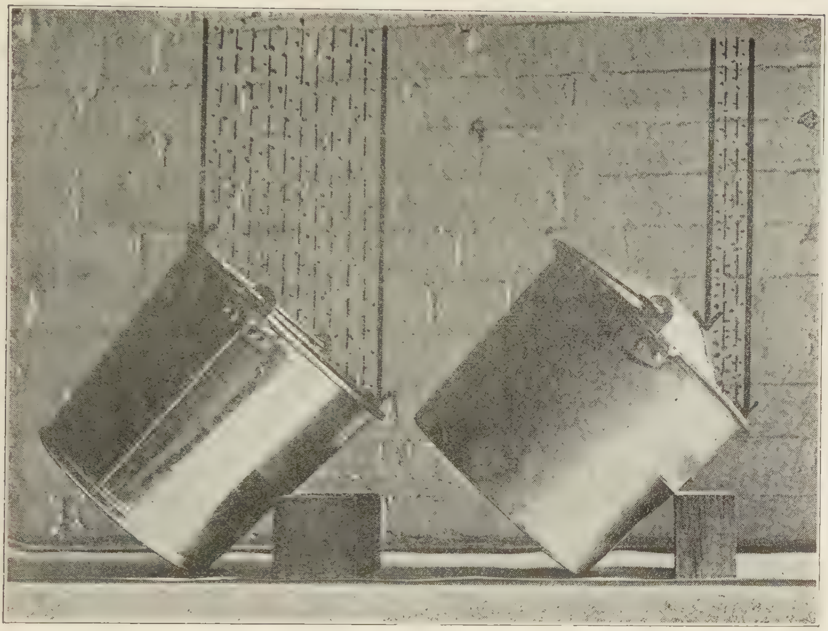
1.—Clean milk production.
2.—Immediate separation.
3.—Proper cooling and storing.
4.—Thorough washing and sterilization of utensils.
5.—Frequent delivery.

Clean Milk Production

The stable air, condition of the coat of the animal, and bits of manure and hair are largely responsible for unclean milk production. These sources can be eliminated, or controlled very largely, by clipping the long hairs from the udder and flanks of the cow, by thorough grooming, and by wiping off the udder and flanks with a damp cloth before each milking. Feeding hay, sweeping floors, and bedding the cows should not be done just previous to milking. Dust in the stable air should be eliminated in so far as possible. In every case the small or covered top milk pail should be used.

In Figures 1, 2, 3, and 4 are shown glass plates or flat dishes with covers containing a specially prepared jellylike substance (culture media) which is used in growing bacteria for experimental purposes. Each white spot or mass in the dishes represents a colony containing millions of bacteria which developed from a single organism. A study of these pictures will show the importance of removing the milk from the stable as quickly as possible after milking, of avoiding dust at milking time, and of clipping and washing the cow's udder and using a covered top milk pail.

Good Cream Production Begins With a Clean Healthy Cow.



A Covered Top Milk Pail Keeps Out Much of the Falling Dirt.

The two plates shown in Figure 1 were exposed for ten minutes to the air in a clean milk room. The comparatively small number of colonies of bacteria that developed on these plates was due to the freedom of the air from dust which serves as a carrier for the bacteria.

The two plates shown in Figure 3 were exposed to the air in the same stable as those in Figure 2, but just after hay had been put down the chute. Dusty hay contains millions of organisms which produce gassiness when they get into the milk supply. The presence of large numbers of these organisms on the dust in the air immediately after haying the cows is an important source of milk contamination. Any practice such as sweeping the floors, cleaning and bedding the stalks, or grooming the cows always increases the dust and hence the bacterial content of the air. It follows then that, if milk of a low bacterial count is to be produced any practice that stirs up dust previous to milking must be discontinued.

The plates shown in Figure 4 were exposed during the period of milking to the falling dirt and hairs under an unwashed udder. The growth of bacteria shown on these plates indicates an important source of milk contamination, which can be largely eliminated by dampening the cow's flanks and udder with a damp cloth and using a covered top milk pail.

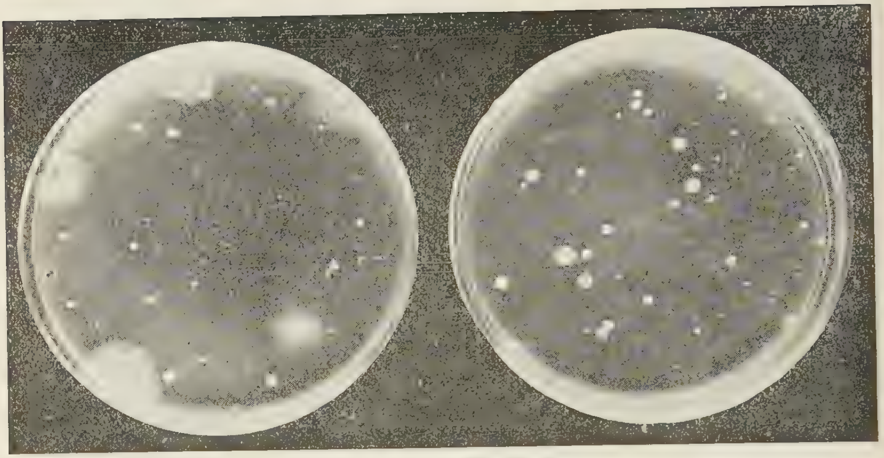


Fig. 1.—Sterilized glass plates containing culture media, which were exposed to the air of a clean milk room for ten minutes. Note the relatively small number of colonies of bacteria.

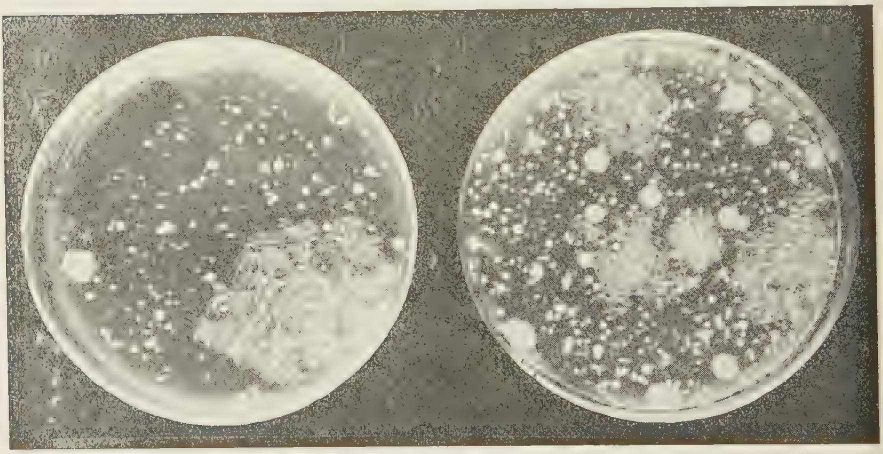


Fig. 2.—Plates exposed to the air of a stable. The plate on the left was exposed five minutes and the one on the right for ten minutes.

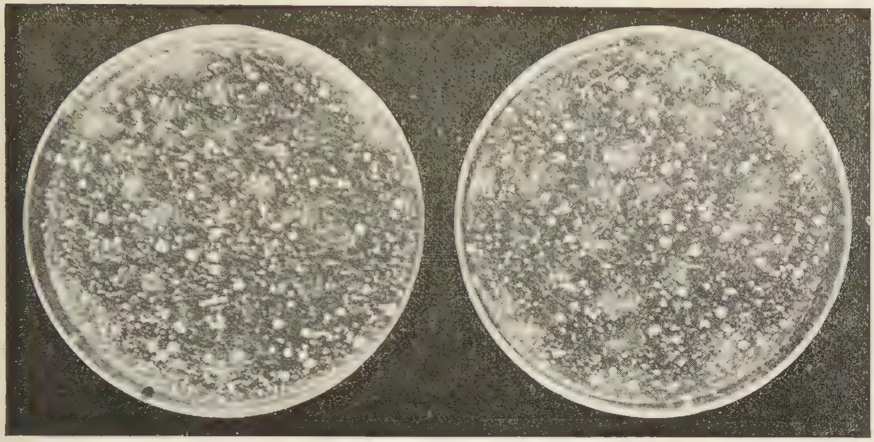


Fig. 3.—Plates exposed to the air of the same stable as those in Figure 2, but just after hay had been put down the chute. The large number of colonies of bacteria indicate the presence of enormous numbers of bacteria on hay dust. The plate on the left was exposed five minutes and the one on the right ten minutes.

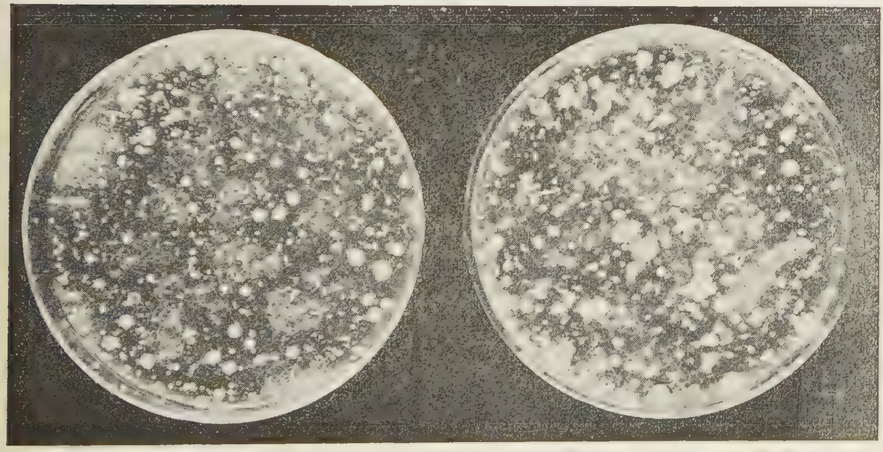


Fig. 4.—Plates exposed to falling dirt and hairs under the unwashed udder of a cow during the milking process. Note the large number of colonies of bacteria.

The strainer cloth may be a seeding bed for bacteria. A wire strainer has the objection that it is difficult to keep clean. Milk and dirt become lodged in the meshes of the wire cloth where they serve as a food supply for bacteria. Common coarse salt worked through the meshes of the wire cloth takes out most of the dirt. Cloth strainers have an advantage in that they are inexpensive and can be replaced at little cost. If cloth strainers are used more than once they must be washed, scalded, and dried. Milking through a cheese cloth is an unsanitary practice, for, although the cloth excludes hair, bits of straw, manure, and large particles, it holds the more soluble dirt until it is washed through by the streams of milk.

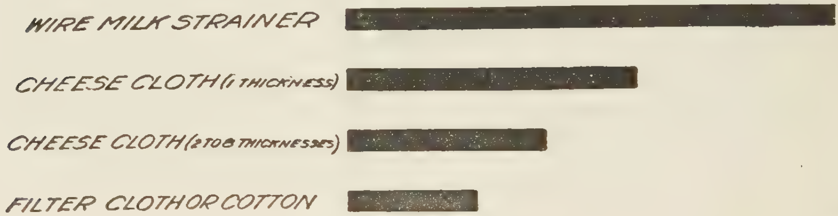


Fig. 5.—Proportional amount of sediment in milk after straining through different materials.

Immediate Separation

The milk should be separated as quickly after milking as possible and not allowed to stand around the stable to absorb odors. Milk separates best when warm. In case the milk becomes cooled it should be heated again to about 90 degrees Fahrenheit, although milk may be skimmed satisfactorily at a wide range of temperatures, varying from 80 to 150 degrees Fahrenheit. Sour milk or milk that is turning sour cannot be separated, as it will soon clog the machine.

In separating the milk should not be turned on until the separator is up to full speed, and this speed should be maintained until the last milk is out. The bowl should then be flushed out with warm water until the discharge from the cream spout appears watery.

The cream screw of the separator should be adjusted to skim a cream testing between 30 and 40 per cent fat. A thinner cream than this means that skim milk which otherwise could be used for calf or pig feeding is being removed from the farm. A heavier cream than this means a loss of fat in skimming, through sticking to the sides of the separator tubes, and through transferring from one vessel to another.

With other conditions remaining the same, the richer the cream the longer it will remain sweet. Cream deteriorates or "sours" because the micro-organisms present change the milk sugar to lactic acid. The milk sugar is present in the skim milk or serum, therefore, the more skim milk removed from the cream, the less sugar will be present upon which the organisms may feed.

Proper Cooling and Storing

The cream should be cooled immediately after separation by placing the can of cream in cold water. The quicker this is done the higher will be the quality of the cream. Water cools cream about forty times faster than air. West Virginia well and spring water is usually below a temperature of 55 degrees Fahrenheit. With the easy access to this water an economical method of cooling cream is afforded many farmers.

A cooling tank so constructed that the water, in passing from the pump or spring to the watering trough, will be delivered at the bottom, thus allowing the warmer water to flow out near the top, gives the best results. The cooling of cream by placing it in the cellar where it will absorb odors is a bad practice. Warm cream should never be mixed with cold cream, but first cooled to the same temperature and then mixed by stirring vigorously.

Thorough Washing and Sterilization of Utensils

There are four steps in thorough cleansing of dairy utensils; namely, washing, rinsing, scalding, and drying. If one of these steps is omitted it is soon noticeable. The utensils should be washed first

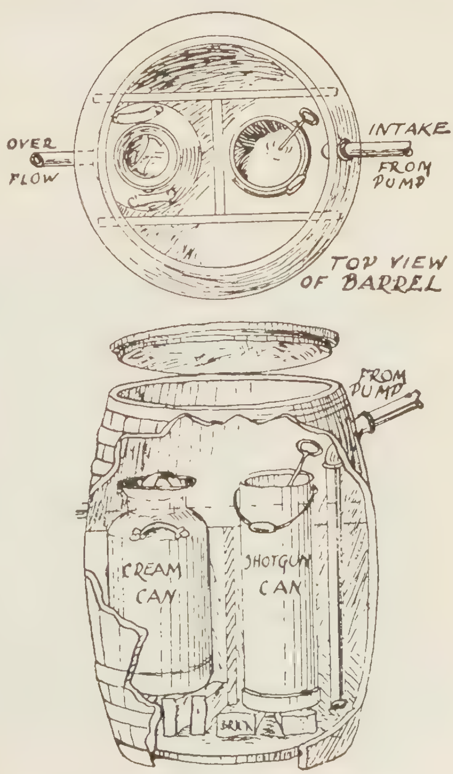


Fig. 6.—Barrel cooling arrangement.

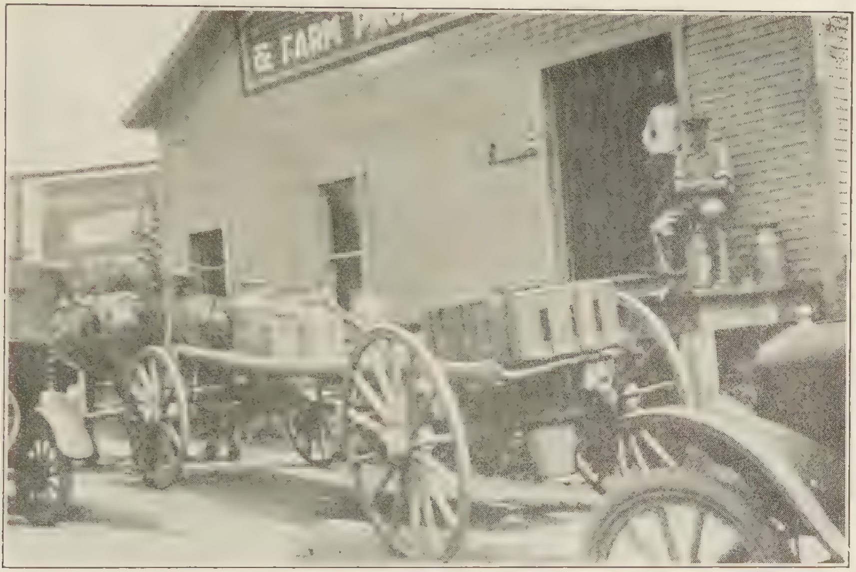
in cold water and then in warm water containing a washing powder. Vessels which have contained milk should never be washed first in hot water as this will cause the milk to stick to the vessel, making it very difficult to remove.

Baking soda is very good as a cleanser since it removes the milk and fat which might adhere to the side of the vessel. Specially prepared cleansing powders can be purchased from local stores at low cost. The use of soap should be avoided as it is hard to remove by rinsing and is likely to find its way into the milk.

After washing, the rinsing should be done thoroughly in order to remove all traces of the washing powder. The next step is to place the vessels in boiling or scalding water and allow them to remain a sufficient length of time to heat through. Milk utensils should never be wiped with a towel as the heat of the vessels after scalding is sufficient to dry them and this eliminates danger of recontamination. The vessels should then be removed from the hot water and placed in the sun to air and dry. Care should be taken that the sunning bench is in a place protected from dust.

The cream separator should be taken apart and all parts thoroughly washed after each time that it is used. The parts should also be sunned and aired every day. It is not enough to run water through the machine, as is sometimes practiced, and allow it to stand until the

Dairy Utensils Should Have a Daily Sun Bath.



During Transportation These Cans Should Have Been Protected From the Sun.

next time it is to be used, and if such a practice is followed the production of first grade cream is impossible.

Frequent Delivery

During the summer the cream should be delivered at least every other day. In winter twice a week is sufficient. Clean production and proper cooling enables one to produce cream that will keep longer, yet cream that is kept for a considerable length of time, though still "sweet" will become musty, stale, or have an "off" flavor.

A wet sack or blanket thrown about the cans during summer delivery will keep the cream cool and in many cases the temperature will be lower when the cream is delivered at the station than when taken from the cooling tank. If the cream is to be shipped, a wet blanket thrown about the can at the station is advisable.

Grades of Cream

An understanding of the market grades of cream, its requirements, the characteristics of each grade, and how to produce it are as essential to the dairy farmer as to the creameryman. Without such knowledge the producer labors blindly without any definite goal toward which to center his efforts. In general the grades of cream adopted by the manufacturers of dairy products are as follows:

First Grade cream shall be that which is clean, sweet, and free from all undesirable flavors or odors.

Second Grade cream shall be that which may be slightly sour, which may contain undesirable flavors and odors to a moderate degree, which may be slightly foamy, yeasty, or "off" in flavor, or which may be too old or stale to grade as first.

Third Grade or rejected cream consists of cream which is putrid, cheesy, rancid, curdy, musty, dirty, or otherwise unwholesome and should not be accepted by the creameryman.

Probably the greatest difficulty in producing first grade cream is in keeping it sweet. In case the cream is held for a sufficient period that it must go as a second, trouble is often encountered in keeping it free from objectionable flavors and odors.

Scoring of Cream

The cream buyer scores cream on the basis of what the butter made therefrom will score. First grade cream then will make butter scoring 91 points and upward; second grade 88 to 90; and third grade 87 and below. On the butter score card, flavor is allowed 45 points as compared to 25 for body and texture, 15 for color, 10 for salt, and 5 for package. The butter flavor is obtained from and identical with the flavor found in the cream from which it is made.

Flavor Defects

There are two general classes of flavor defects:

1.—Those which are absorbed from the surrounding environment, feeds, and stable air, or resulting from the abnormal functions of the cow.

2.—Those developed by the growth of the various micro-organisms present in the cream.

ABSORBED FLAVORS

A list of the more important of the absorbed flavors are as follows:

Weedy cream is caused by the cows eating such weeds as garlic, onions, rag-weed, or any weed possessing a strong odor. Garlic or onion flavor is very noticeable. Experiments have shown that this flavor was present in milk drawn as soon as three minutes after feeding garlic and was noticeable in the milk drawn ten hours after feeding. The safe way of eliminating this flavor is by keeping the cow off pastures containing these objectionable weeds. This flavor is particularly noticeable in early spring or late summer.

Feedy cream is quite common, being due to exposing milk to such feeds as silage or it may be due to cows eating such feeds as

roots, turnips, or other strong flavored feeds. Such flavors are apt to be more noticeable during the winter months.

Gasoline cream is caused by exposure to gas engine room. Since gasoline is so volatile, its gas permeates the entire room and is readily absorbed.

Oily cream is due to carelessness in oiling the separator or handling oil about the milk. This flavor is carried over into the butter more so than many others and is particularly objectionable.

Cowy cream is more noticeable during the winter months when the cows are stabled most of the time. This flavor resembles the odor of a cow. It may be due to poor ventilation, unclean stable, or bits of manure in the milk.

"Off" flavored cream is a term applied, when there is a peculiar undescribable flavor present, not characteristic to milk. The same term is used in describing butter made from such cream.

Cellar flavor cream is the result of exposing cream to vegetables, sauerkraut, fruit, and foods usually kept in the cellar, or to characteristic odor associated with the cellar.

Smothered cream is liable to result where the cream is cooled down in a covered receptacle, thus prohibiting the escape of the natural heat. This flavor can be driven off largely by aeration.

DEVELOPED FLAVORS

There are not so many undesirable developed flavors in cream because the micro-organisms responsible for the "souring" of milk grow so much faster than the others and by so doing retard the development of those producing undesirable flavors. Among the most common of these flavors are as follows:

High acid cream is caused by the growth of an organism which grows best at 70 to 75 degrees Fahrenheit. This flavor ranges from "slightly sour" to "very strong" or "rancid." These organisims are present at the time the milk is drawn from the udder, but the numbers on the milk utensils if they are not thoroughly washed and dried. Immediate cooling to below 50 degrees Fahrenheit retards their growth and insures the cream against a high acid flavor.

Cheesy cream has the flavor of an aged Cheddar cheese, such cream has usually been held for a considerable length of time at low temperatures. This flavor is a result of the decomposition of the curd in the cream.

Yeasty cream is particularly noticeable during the summer because of its foaming and sometimes blowing the lids off the cans. The cream becomes contaminated from dust, dirt, and the utensils. Thorough

washing and scalding of all utensils and cooling of the cream will eliminate this trouble.

Slimy or ropy cream may be noticed in the spring or fall of the year or at a time when there are stagant pools of water to which the cows have access. These places should be drained, the cows brushed, udders wiped with a damp cloth, and clean, well-scalded utensils used. Slimy or ropy cream is not harmful yet it is very repulsive.

Bitter cream flavor may be the result of giving cows access to pastures where objectionable weeds such as rag-weed are found. It may be caused by holding cream at low temperatures for a long time. Some cows in the advanced stage of lactation produce bitter milk.

Greasy or tallowy cream is the result of unclean production and is noticeable in old cream.

Fishy cream tastes like herring. Such a flavor is very objectionable when present in cream and butter. It may result from unclean production and holding for a long time at low temperatures.

Flat, watery cream approaches a state of being tasteless and odorless. It may result from allowing too much of the flush water to pass into the cream. This flavor is also characteristic of frozen cream.

Need for Cooperation

In the technique of buttermaking the American buttermaker is superior to those of other countries. By proper manipulation he can make a salable piece of butter from fairly poor cream, but he cannot make the best butter unless the cream received is of high quality. It is up to the farmer to produce a better quality cream and he should justly take pride in delivering a clean, sweet, smooth cream to the creamery.

It is true that some operators may not take the best care of the cream after it has been delivered to them, but this should not be used as an excuse for unclean production. The buttermaker does ripen the cream after it is brought to him, but he has control of the ripening at all times.

Receiving sour cream from a number of sources, mixing them together, and attempting to make good butter therefrom is about like a dozen or more people mixing dough and bringing it all to a baker to bake the best bread, it cannot be done.

On the other hand the creamery operator by his attitude, his cleanliness, and his encouragement has a large influence upon the quality of cream produced. It is an incentive to bring a high grade

cream to a creamery which is clean, sweet-smelling, and attractive. The creamery should be well-lighted and ventilated, have clean walls, and present an attractive appearance in general. The operator should see that the employees' clothes are clean at all times. The cans returned to the patron should be well washed and steamed ready for use without further washing.

In order to encourage sweet cream production, a few cents more per pound of butterfat should be paid for sweet cream than for sour. Cooling tanks should be advocated. These may be furnished to the patrons at cost on a time basis, deducting a little from their check each month until they are paid for. The difference in the price of the cream will soon pay for them and the patrons will be well satisfied to have a small amount deducted from each check.

There is a great demand for good butter. Until a higher grade cream is produced throughout the entire country, this demand will never be met. Cooperation between the producer and creamery operator will work wonders toward reaching this aim.

Demands are increasing in West Virginia for more and better cream. These demands come from many sources, such as creameries, ice cream factories, and the rapidly increasing city population. Each one of these markets require a high grade cream.

Practically 85 per cent of the cream used as table cream and in ice cream manufacture in West Virginia is produced outside the state. This condition assures the West Virginia dairy farmer a market for high quality cream.

Circular 44

March, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

Water Systems for Farm Homes

By
F. D. CORNELL, Jr.

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

SUMMARY

1.—The farmer can do no other one thing so vital to his welfare and that of his family as to make the farm water supply SAFE for use.

2.—Adequate protection of the farm water supply costs but little and is valuable insurance.

3.—Running water in the home is a convenience that none who have had it would willingly be without.

4.—It is not necessary that a complete water system be installed at once. Starting with a simple installation one may gradually add to it.

5.—West Virginia conditions make the installation of a running water system on many farms comparatively simple.

6.—In a survey of more than 500 West Virginia farms, all complete water systems found has been installed at a cost of from $300 to $400.

7.—All factors considered, galvanized wrought iron pipe is best for service pipe on the farm.

8.—The size of pipe used has a very important bearing on the successful working of the water system. Pipe of too small a diameter is often used.

Water Systems for Farm Homes

A happy home life and good health are important contributing factors to success on the farm. Time and money spent by the farmer in helping to remove the drudgery from home tasks will yield returns more than commensurate with the amount of capital invested, because freedom from drudgery helps to preserve happiness and health and creates an atmosphere of contentment.

The installing of some type of water system in the home is an excellent example of this kind of investment. It eliminates much back-breaking labor and miles of travel in carrying water, makes work in the home lighter, and is a convenience to the whole family. Such labor saving devices have their place in the home, just as labor saving machines have on the farm, and are worthy of some sacrifice, if necessary, to make them a reality.

That farmers have not made more progress in the installing of water systems may be attributed either to the fact that many have never thought of it; that few realize the importance of such a step; that many do not know how to go about installing a system; or that they refrain from making such improvements for financial reasons.

Since it is felt that many more water systems would be installed if the farmer knew how to plan and install the system best suited to his conditions, the following discussions are presented in order that the need for such information may be at least partially satisfied.

ADEQUATE PROTECTION OF WATER SUPPLY NECESSARY

The first important consideration in installing water in the home is the proper protection of the supply at the source, thereby making it safe for use at all times. The necessity for this step is indicated by investigations of which the following examples are typical.

"Investigations indicate that about three out of four shallow wells are badly polluted.*

Of the water supplies on 79 selected farms in Minnesota, 20 were good and 59 polluted, largely due to poor location and lack of protection.†

The Indiana Board of Health in examining 177 deep well water

*Farmers' Bulletin 1227.
†Farmers' Bulletin 549.

supplies found 116 good, 45 bad, and 16 doubtful. Of 411 shallow well supplies, 159 were good, 309 bad, and 43 were doubtful.*

E. Bartow of the Illinois State Water Survey found that three-fourths of the shallow wells of the state were contaminated.*

Professor E. W. Lehmann in examining 50 water supplies in Missouri, 48 of which were from cisterns and 2 from shallow wells, found that the 2 shallow wells and 40 of the cisterns showed contamination.*

To insure a safe water supply it is necessary that one have a knowledge of how sources become contaminated and how they may be protected. Briefly stated, the water supply on farms is usually obtained from one of four sources: dug wells, drilled wells, springs, or cisterns.

Dug Wells

Dug wells are found most frequently as the source of water supply on farms in West Virginia.† They are of necessity seldom less than three feet in diameter and are usually walled with field stone. Since the windlass is still very commonly used, many wells are not adequately protected at the surface.

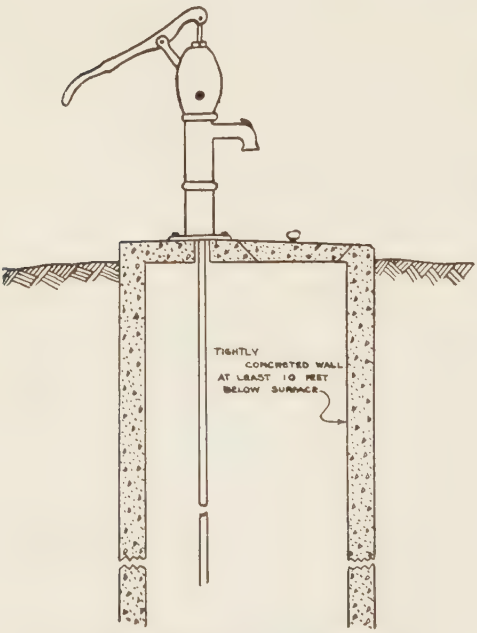


Fig. 1.—A Dug Well Properly Protected.

Bacteria are found in the upper layers of soil. Soil at a depth of ten feet or more is practically sterile. If the wall of the well, therefore, is made water tight down to a depth of at least ten feet, the danger of contamination from seepage would be very greatly minimized because surface water would have to filter through ten feet of soil before it could enter the well, provided, the well was tightly covered.

There is one other step, therefore, which should be taken in protecting a dug

*Keeping the Water Supply Pure, E. W. Lehman, Trans. Amer. Soc. Agr. Engrs. 1921.
†West Virginia Agricultural Experiment Station Bulletin 206.

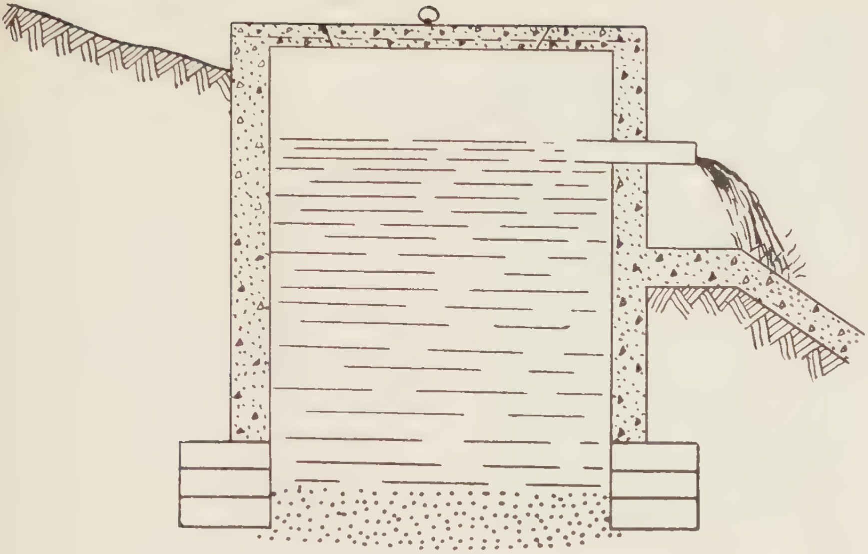


Fig. 2.—Spring Encased With Concrete and Protected by Tight-Fitting Cover.

well, and that is to place a tight curb and cover over the well in order to prevent the entrance of surface waters, and to prevent dirt, leaves and animal filth, even animals themselves, from falling or being washed into the well. (See Figure 1).

All of this assumes that the well has been properly located. It must be remembered that a well located near or below a cesspool, barn, hog pen, privy, or similar source of filth, is always in serious danger of pollution.

Drilled Wells

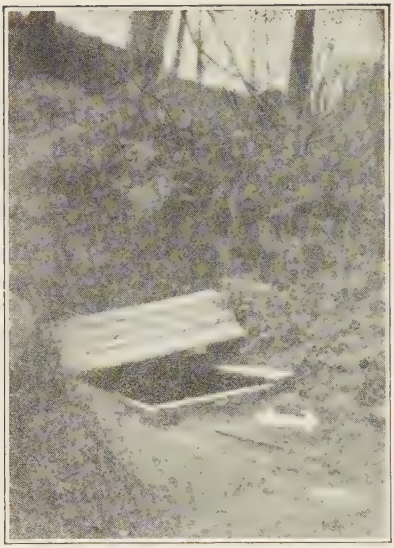
Drilled wells do not present the same problems of sanitation as do dug wells. In drilled wells, there is an impervious casing extending down at least as far as the rock stratum, thereby practically eliminating the danger of contamination from seepage. The protection of the well at the surface is also more easily accomplished.

Where one has to go to depths greater than forty feet for water, a drilled well is to be preferred. The dug well possesses some advantages, however, such as softer water, and shorter lifts.

Springs

Because of their frequent occurrence, springs are a very common source of water supply on West Virginia farms.* Springs are a natur-

*West Virginia Agricultural Experiment Station Bulletin 206.



A Poorly Protected Spring is an Unsafe Source of Water Supply.

al emergence of ground waters at the surface and by simply enlarging the basin a good supply of water may be obtained.

In protecting spring waters against pollution two things are of vital importance. First, the spring should be encased, preferably with concrete, thereby making tight walls that will retain the water and prevent the entrance of seepage which is apt to be polluted. Secondly, the spring should be tightly covered to prevent the entrance of any foreign material from the surface. (See Figure 2.)

Since spring waters are near the surface, it is well to know the direction of flow to the spring. This gives opportunity to prevent or remove any filth accumulations from which pollution might be carried to the spring by seepage. It is also important to know points at which water enters the spring basin in order that openings may be left in the wall to permit its entrance.

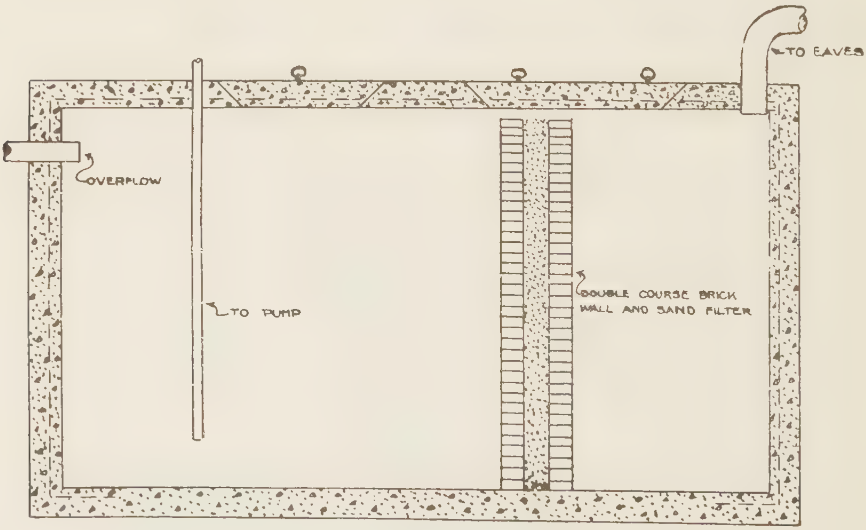


Fig. 3.—A Satisfactory Type of Cistern, Showing Brick Filter.

Cisterns

The cistern is coming to be used more extensively as a source of farm water supply.* One advantage is that it furnishes a supply of soft water.

The cistern should be constructed of some durable material such as concrete or brick. It can be made water tight by using a fairly rich concrete mixture (1-2-3), properly spading it in the forms, and painting the inside with a mixture of cement and water of about the consistency of thick cream.

The cistern should also be provided with some efficient type of filter (See Figures 3 and 4).

A very effective filter, and one easily constructed is the double course brick filter. A space of about four inches is left between the courses, and this is filled with sand. The sand should be replaced each year. When the pores of the brick become clogged they may be cleaned with a stiff wire brush. If the brick are not cleaned when the pores become clogged, the effectiveness of the filter is lost.

The spouting from the roof to the cistern may also be equipped with a device for discarding the first run-off from the roof, which is apt to contain dust, dirt, leaves, bird excrement, etc., thus preventing the entrance of such matter into the cistern.

The size of the cistern is determined by the roof area, the regional rainfall, and the number of persons and animals to be supplied.

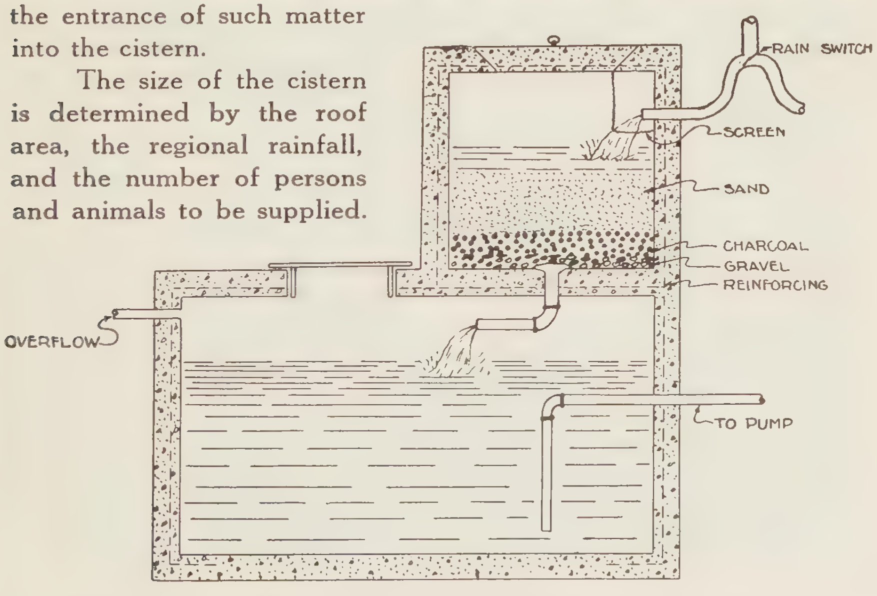


Fig. 4.—A Well Constructed and Efficient Cistern and Filter.

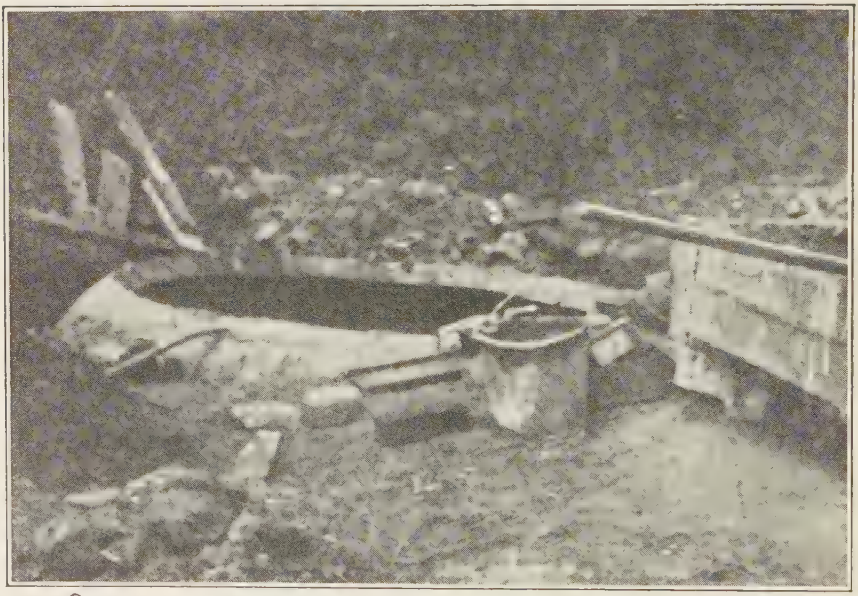
*West Virginia Agricultural Experiment Station Bulletin 206.

In general, the cistern should be large enough to hold at least a month's supply, since there are often extended periods when there is little or no rainfall.

Table 1 shows the amounts of water allowed for various purposes on the farm in figuring the size of storage tanks needed.

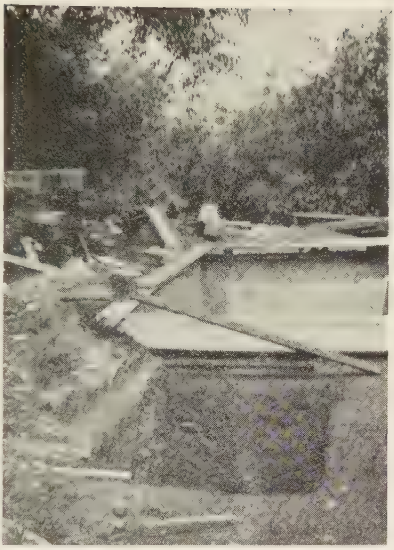
TABLE 1.—Quantities of Water Needed per Day.

Purposes for Which Needed	Gallons Per Day
One Person (no bath equipment)	8–10
Per Person (including bath equipment)	20–30
For a Horse	5–10
For a Cow (including amounts for cleaning utensils and stable)	15–20
For a Hog	2–2.5
For a Sheep	1– 2



A Circular Storage Tank Constructed of Brick for Use With a Gravity Water System. Brick Tanks Should be Well Plastered on the Inside With a Rich Cement Mixture to Make Them Water-Tight. (See Discussion on Pages 13 and 14).

As an illustration of the relation of "roof area" and "regional rainfall" to the size of the cistern, a typical example should suffice.



A Rectangular Concrete Storage Tank Under Construction for Use With a Gravity Water System. (See Discussion on Pages 13 and 14).

According to the figures of the United States Weather Bureau, Washington, D. C., covering a period from 1891 to 1925, the average annual precipitation in West Virginia was 42.74 inches. Assuming that water is to be collected from the roof of a barn 28 by 58 feet and the roof overhangs one foot on all sides, the number of gallons that would go into the cistern would be the amount of water that would fall on an area 30 by 60 feet. To determine the number of gallons that would fall on this area, multiply the length of the roof by the width of the roof area; then multiply this product by the annual precipitation and divide the final product by 1.6 or $\frac{30 \times 60 \times 42.74}{1.6} = 48{,}082$ gallons. Some allowance must be made, however, for waste, evaporation, loss by blowing of wind, etc. Therefore, one-third ($\frac{1}{3}$) of the above figure is taken away to account for these losses, or $48{,}082 - 16{,}027 = 32{,}075$ gallons. Since it is estimated that only one-fourth of this amount is in the cistern at any one time, the largest cistern necessary to store water from this roof would have a capacity of 8,019 gallons (See Tables 2 and 3). This cistern would then furnish water sufficient to supply a family of four persons where the home is fully equipped with running hot and cold water, bath, and laundry equipment, or nine persons where the water is carried from the outside. Since the annual precipitation varies so greatly in different sections of the state, it is advisable to obtain the figure for annual precipitation from the nearest weather station.

RUNNING WATER SYSTEMS FOR THE HOME

A Simple and Inexpensive Installation

Many farmers feel that the installing of conveniences in the home can come only when there is a goodly bank surplus to pay the bills. As a matter of fact, a beginning can be made which will cost but little, and further additions to the system can be made as funds become available.

One of the simplest installations, which costs comparatively little, and proves to be a real saver of time and labor, is the placing of a pump in the kitchen.

Where the vertical lift is not more than 20 feet, a pitcher pump may be installed, as shown in Figure 5. The cost of piping, pump, and sink for such a system is comparatively low, rarely more than $20, and the task of putting it in is so simple that no skilled labor is required. In case the vertical lift exceeds 20 feet, a force pump will be necessary. The pitcher pump will draw water laterly a distance as great as 50 feet. For those who desire the convenience of water inside the house, but who feel they can afford to invest very little in obtaining it, this type of installation is recommended.

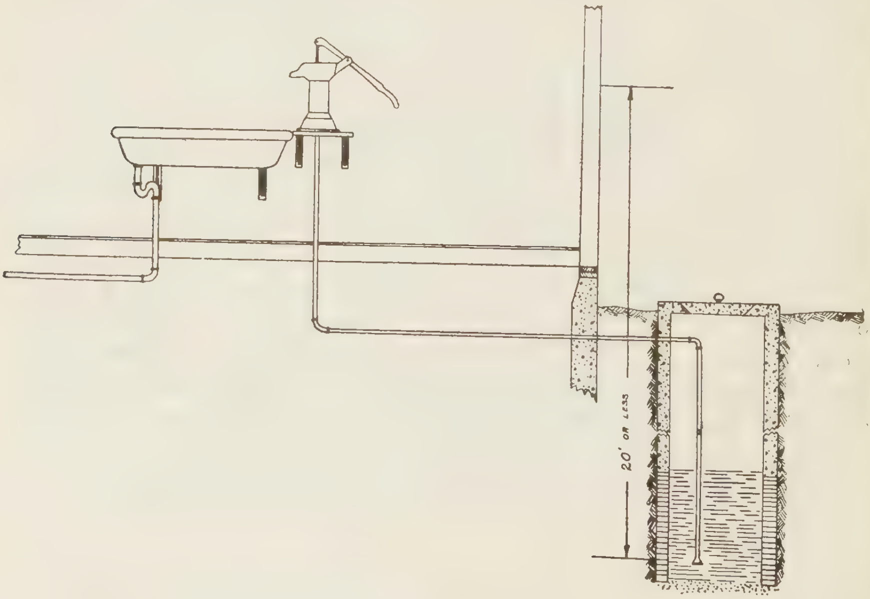


Fig. 5.—A Simple Pitcher Pump Installation.

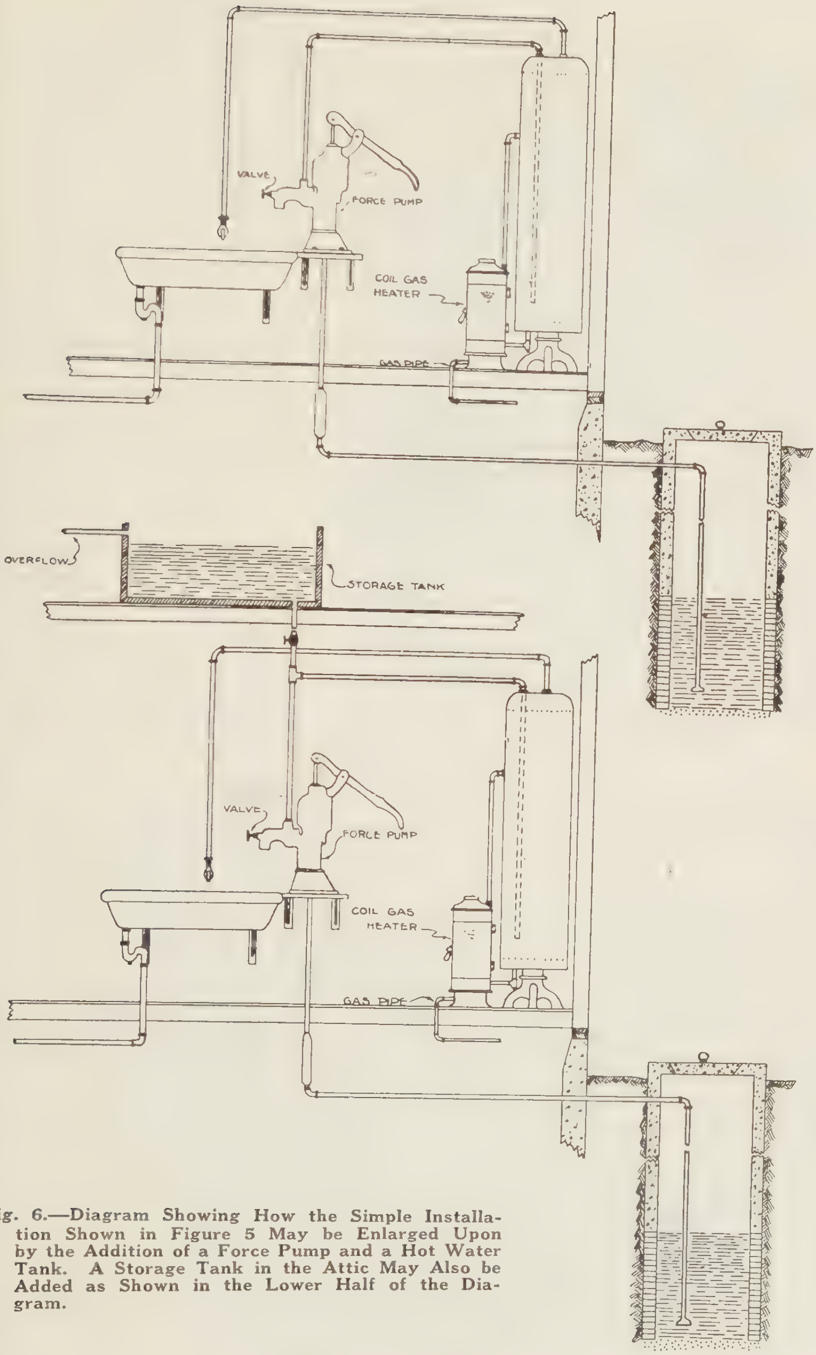
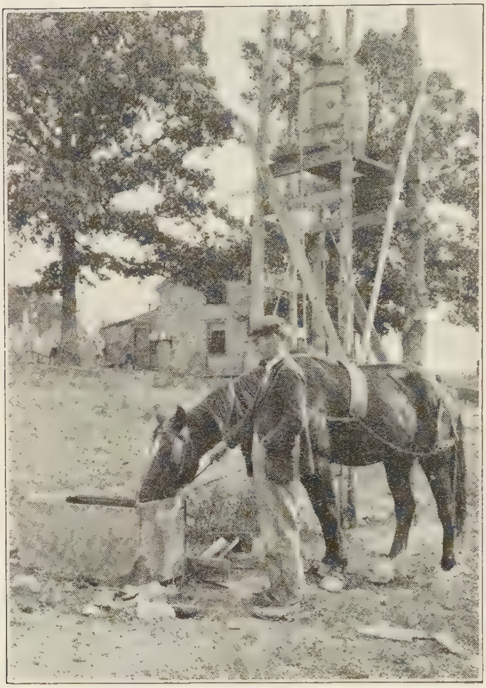


Fig. 6.—Diagram Showing How the Simple Installation Shown in Figure 5 May be Enlarged Upon by the Addition of a Force Pump and a Hot Water Tank. A Storage Tank in the Attic May Also be Added as Shown in the Lower Half of the Diagram.



Even Crude Devices Are Often a Step Toward More Permanent Equipment.

If it is desired at some later date to add to this system in order to obtain hot water also, it can easily be accomplished by providing a pump with a special valve and installing the hot water tank and necesary equipment. Where gas is available, as it is in numerous sections of West Virginia, the water may be heated by a coil gas burner of the type shown in the upper half of Figure 6. Or, in case gas is not available, the water may be heated by connecting the tank with a waterfront in the kitchen range. This makes posible an inexpensive hot and cold water system, and one that is easily and cheaply installed. In this system the hot water faucet should always be left open in order to take care of the expansion and thus prevent the development of too high pressure in the tank. To obtain hot water it is necessary to close the valve in the spout and operate the pump.

The valve shown in the spout of the force pump serves three uses. When clear out, it closes the spout so that water may be pumped to an elevated tank. When clear in, it closes the pipe so that water cannot return from the tank to the spout or pump. When in this position, if the pump is operated, water will be delivered at the spout. If the valve is half-way in it allows water to flow from the storage tank through the spout as in an ordinary faucet.

A still further development of the system may be made by constructing a storage tank in the attic, and using the pump to force water to it as shown in the lower half of Figure 6. From there it will run back by gravity, providing a system of running hot and cold water. Such additions as are here outlined can be made to the origional installation from time to time, whenever desired.

A safe and abundant water supply is appreciated to the greatest extent, however, when it is most convenient. The progressive farmer recognizes the desirability, therefore, of a water supply system which will provide a constant flow of water without hand labor. He sees in it a considerable saving in labor for himself and his family, a source of comfort and convenience in his home, and a means for the provision of an adequate system of sewage disposal which will be a safeguard for the health of the family.

Recognizing these features which recommend the water supply system, the farmer is confronted with two problems. The first of these is what type of water system is best suited to his individual conditions. The second question is a matter of cost.

Gravity Water Systems

Many types of gravity water systems may be installed, depending upon the individual conditions. All, however, work on the same principle. A supply of water is located at an elevation enough higher than the point of delivery that the water is obtained under sufficient pressure. Sometimes water may be piped directly from the source of supply; often an elevated tank is used; storage tanks are sometimes located in the attic, or barn, or water may be pumped from a lower level to a reservoir on a nearby hill and returned from there by gravity.

Because of the frequent occurence of springs, and because of the topography, a comparatively high percentage of farmers in West

Running Water at the Barn Saves Time and Labor.

Virginia have conditions such that by merely enlarging the spring basin and constructing a tight and well protected reservoir there, (See illustrations on pages 8 and 9), water may be piped to the house directly by gravity. In most cases where this may be done, the distance that the water would have to be piped is less than 300 yards.* These conditions are ideal for the installing of a running water system, and require a minimum of equipment. If the source is not at an elevation sufficient to deliver water to the second story under sufficient pressure, the bathroom may be located on the first floor.

Very simple gravity systems have been found that at least effect a saving in the carrying of water for household uses. One ingenious West Virginia woman had a cistern constructed in a hillside which sloped sharply up at the rear of the house. Into this cistern was run the water from the roof. The cistern was just high enough to deliver the water at the kitchen sink, thus making a very simple installation.

The cost of a gravity system when water is piped directly to the house is confined to the cost of the pipe, kitchen and bath equipment, construction of the reservoir, and any labor costs connected with the installation. The cost of plumbing fixtures for the kitchen and bath includes a wide range, depending upon the type and quality prefered.† The best indication of the cost of such a system may be obtained from the fact that all complete systems of this type found in a survey of more than 500 West Virginia farms, had been installed for from $300 to $400. This does not include, of course, any estimate of labor; it merely represents the actual cash outlay.

Where water cannot be piped directly to the house from the source of supply, it is necessary to employ some means of forcing it to a higher level. The most satisfactory system of this type is one where the storage tank can be located on a rise of ground near the house. By installing a pump at the source of the water supply, forcing the

TABLE 2.—Capacities of Rectangular Cisterns or Storage Tanks in Gallons and Barrels (31½ gal.).

Depth in Feet	Length and Width in Feet									
	6 by 6		6 by 8		8 by 8		8 by 10		10 by 10	
	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.
5	1350	43	1800	57	2400	76	3000	95	3750	119
6	1620	51	2160	68	2880	91	3600	114	4500	143
7	1890	60	2520	80	3360	106	4200	133	5250	166
8	2160	68	2880	91	3840	122	4800	152	6000	190
9	2430	77	3240	103	4320	137	5400	171	6750	214
10	2700	85	3600	114	4800	152	6000	190	7500	238

*West Virginia Agricultural Experiment Station Bulletin 206.
†See pages 23 and 24 for a discussion of plumbing equipment.

TABLE 3.—Capacities of Circular Cisterns or Storage Tanks in Gallons and Barrels (31½ gal.).

Depth in Feet	Diameter in Feet									
	4		5		6		7		8	
	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.	Gal.	Bbl.
5	470	15	735	23	1058	33	1439	45	1880	59
6	564	18	881	28	1269	40	1727	55	2256	71
7	658	21	1028	32	1481	47	2015	64	2632	83
8	752	24	1175	37	1692	54	2303	73	3008	95
9	846	27	1322	42	1904	60	2591	83	3384	107
10	940	30	1469	46	2115	67	2879	91	3760	119

water into the tank, and allowing it to run to the house by gravity, a comparatively simple system and one requiring little upkeep cost is secured. The advantage of a tank of the type mentioned is that it can be built of durable materials, and placed underground, thus eliminating the danger of freezing and also assuring a supply of cool water. The capacities of storage tanks are shown in Tables 2 and 3.

Numerous other types of elevated tank systems may be found. In some cases, a storage tank is located in the attic. This has some disadvantages in that there is a danger from freezing, and of damage from leakage, the tank has to be constructed of either metal or wood, and the water in summer months becomes warm. The cost of upkeep is somewhat greater than where the tank may be located underground. Where it is impossible, however, to locate the storage tank on a near-by hill, this type of system works satisfactorily.

Sometimes the tank is built up as an elevated tank near the buildings, but this is expensive. In such cases it would probably be advisable to install some type of pressure system instead. The tank, too, may be located in the barn, but there again the danger of freezing enters in.

Various methods are used for pumping water to the storage tank, the most important of which are the windmill, a single or double acting force pump operated by a small gasoline engine or electric motor, and the hydraulic ram.

The windmill has been tried in some sections of West Virginia and proved unsuccessful, due to the irregular wind conditions which make its use unreliable. On farms, however, where conditions warrant, the windmill furnishes a satisfactory means for pumping water, with an upkeep expense which is relatively low.

The gasoline engine is the commonest source of power for pumping water. By operating the pumping unit at intervals and for comparatively short periods, a goodly supply may be mantained in the tank.

A Windmill Furnishing the Pumping Power on a West Virginia Farm.

Where conditions will permit, a hydraulic ram may be used to force water to the storage tank. Because of the fact that the ram will only deliver from approximately one-tenth to one-seventh of the water that flows to it from the spring, it ought not to be installed unless the flow from the spring is sufficient to operate it. It is not advisable to install a ram unless the flow from the spring is at least three gallons per minute at all seasons of the year, and unless the topography is such that the proper fall in the supply pipe can be obtained without having to go too great a distance.

To have the ram operate successfully, there should be one foot of fall in the supply pipe to every seven feet water is to be lifted vertically. The length of the supply pipe should be equal to the vertical lift, except in cases where the lift is short. If the fall is less than five feet, the length of the supply pipe should be eight to ten times the total fall. The delivery pipe should never be less than one-half inch in diameter because of the friction in the pipe. The ratio between the size of the supply pipe and the size of the delivery pipe is usually two to one. Figure 7 shows the ram in cross section and also a diagramatic representation of an installation.

Water flows from the spring through the supply pipe A to the ram. It gradually gains momentum as it flows on and out of the waste valve C. Finally the water is moving with velocity sufficient to force the waste valve closed. Then the only outlet for the water is through valve E and into the air chamber B. The water, due to the momentum it has acquired, rushes into the air chamber and compresses the air. The weight of the water, and the pressure forces the valve E closed again. The water by entering the chamber against pressure is finally brought to a standstill, thus releasing the pressure against the waste valve which allows it to open again and the operation begins anew. The expansion of the air in the air chamber forces the water through the delivery pipe D. The cost of the sizes of ram found on the farm ranges from $8 to $20.

Innumerable and varied are the applications that are found of the principles involved in the gravity system; from the simplest sort of construction as shown in the picture on page 12 to the complete and much to be desired type of system. Because of this fact estimates of cost can be made for only the complete system, and even these are but approximate since conditions on no two individual farms are the same.

Because of the fact that so many types of power can be used in the gravity system where power is necessary, and because there are such variable possibilities in the kinds of equipment and the amounts of materials used, it is difficult to give any accurate estimate of the

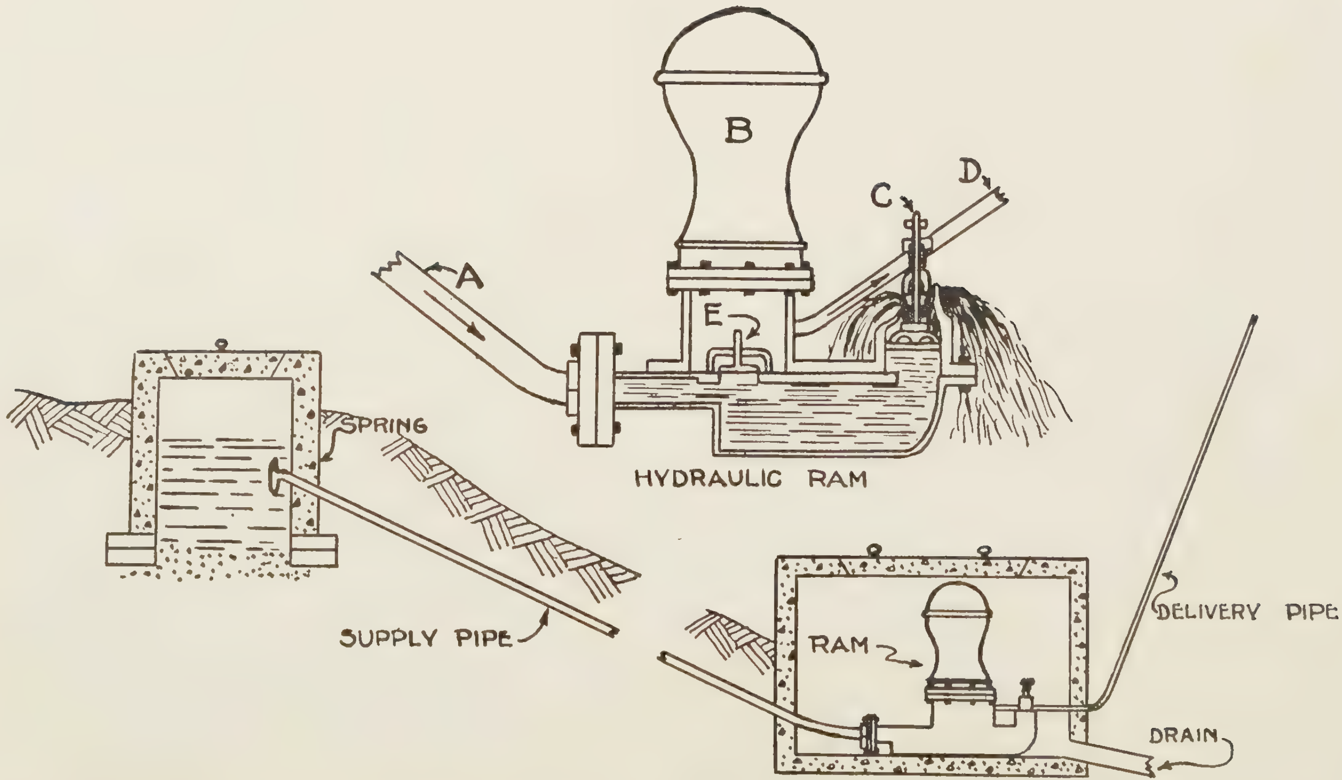


Fig. 7.—Diagram Showing Working Parts and Installation of Hydraulic Ram.

cost of installing this system. From data obtained from the farmers themselves, however, it is safe to conclude that a gravity system of this type, complete with bath, kitchen, and laundry equipment, may be installed under West Virginia conditions, for a cash expenditure of from $300 to $600.

Pressure Water Systems

Where conditions are such that the installation of a gravity system would prove either extremely difficult or too expensive, some type of pressure system may be installed. There are two types of pressure systems on the market: the hydropneumatic and the pneumatic systems.

In the hydropneumatic system a pump operated by hand, a gasoline engine, or an electric motor, forces the water into a large galvanized or black iron storage tank. As water c¬ntinues to enter the tank, the air above the water becomes more and more compressed, thereby creating an increasing pressure on the surface of the water. When a faucet in the delivery system is opened it furnishes an outlet for the pressure in the tank and water is forced through the pipe to the point of delivery.

Since the presure in the tank decreases as the air continues to expand and the quantity of water decreases, it is well to provide a tank of liberal proportions, unless electricity is available. In this case, the system can be made automatic and such a large storage tank is not necessary. If a tank of reasonable size is not provided where a gasoline engine or hand power is used, it means much more careful attention will have to be given the system in order that the tank may be kept supplied with water, and the pressure maintained.

Some advantages offered for this type of system are: (1) There is no danger of damage from leakage as in the case where there is a storage tank in the attic. (2) The tank is usually in the cellar, and the danger from freezing is minimized; also the water is cool in warm weather. (3) With this type of system satisfactory pressure can be obtained at the highest faucet in the house.

The cost of the hydropneumatic system varies with the size of tank, kind of pumping power used, depth of well, etc. The cost of a system for the average farm, however, would range from $100 to $200. In addition to this would be the costs of installation, labor, piping, and plumbing equipment which would bring the total cost of installation to from $300 to $500. Figure 8 illustrates a complete installation using a hydropneumatic system.

In the pneumatic system a gasoline engine or electric motor is used to operate an air compressor which forces air into a storage tank

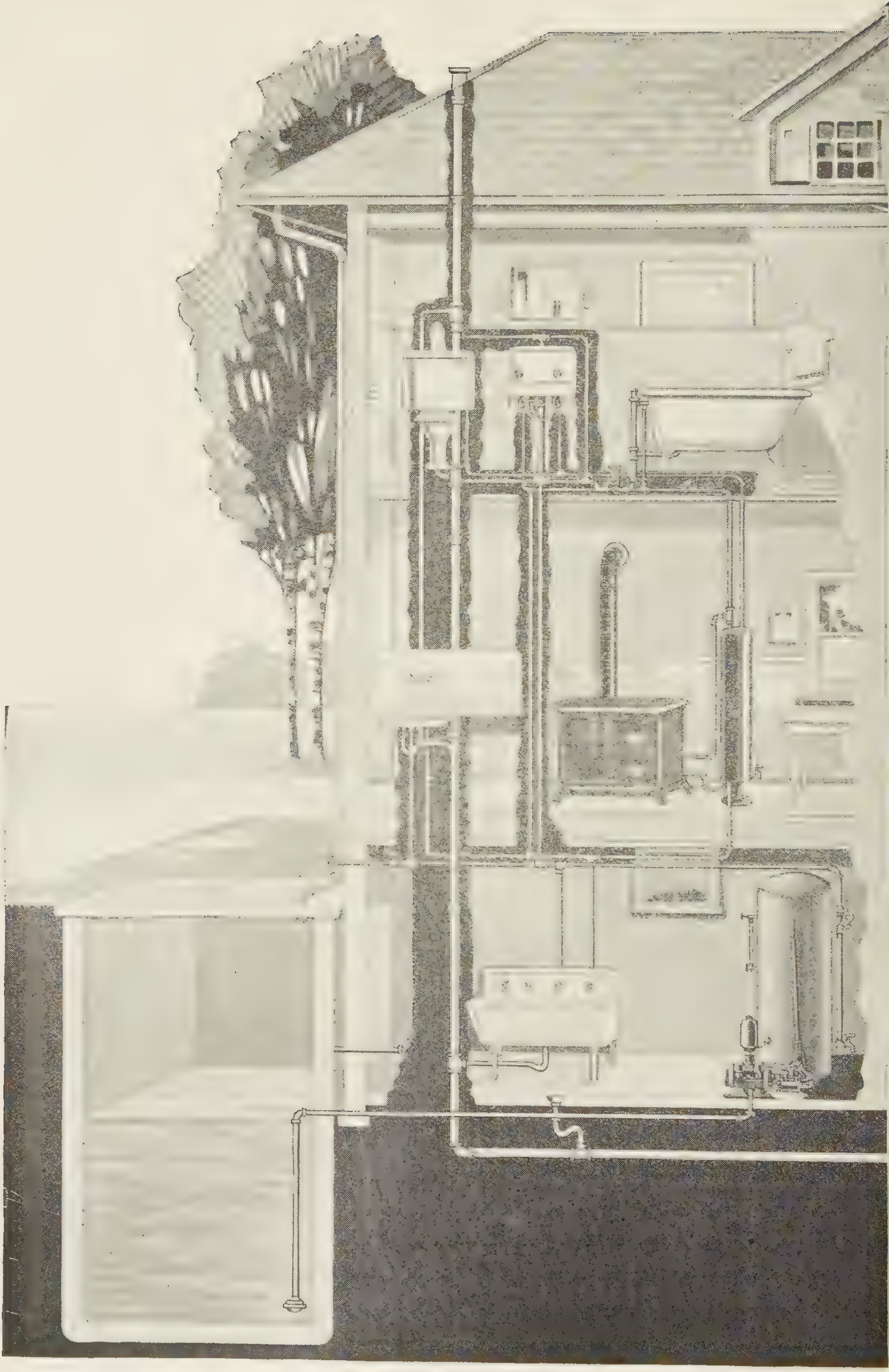


Fig. 8.—A Complete Installation Showing Hydropneumatic Water System. Courtesy F. E. Meyers and Brother Company, Ashland, Ohio.

under pressure. From the tank a line of one-half inch pipe is laid to an air pump located in the well. The delivery pipe is also connected to the pump. When a faucet in the delivery line is opened it furnishes an outlet for the pressure in the air line. The air passing through the pump operates it and causes water to be forced through the delivery pipe. The chief advantage of this system is that it will furnish fresh water direct from the well. Due to a pressure regulating device between the air tank and the pump, a uniform pressure at the pump can be maintained. In case of emergency, such as fire, the device may be thrown out, and the full pressure in the tank allowed to go on to the pump.

In general, this system is somewhat more expensive than the hydropneumatic system. The ideal installation is one where electricity is available because the system can then be made automatic.

In either the hydropneumatic or pneumatic systems the main working parts may be placed where most convenient and safe from freezing.

Service Pipe

Among the kinds of pipe now in use, the four that concern the farmer most for service pipe are lead, brass, wrought iron, and steel.

LEAD

Lead pipe has been used to convey water for centuries. (Its use dates back to the days of Babylon and Pompeii.) As service pipe, however, its use has very greatly declined in recent years. This has been largely due to the fact that certain waters dissolve sufficient of the lead to make the use of the water for drinking purposes dangerous. Cases of lead poisoning have not been uncommon. Lead pipe has been used quite extensively in farm installations where there is a continuous flow of water. In such cases, the danger of poisoning from using the water is confined very largely to the first few days after the pipe has been installed. When the flow is intermittent, however, and water is allowed to stand in the pipe, some other type of service pipe should always be recommended.

Lead pipe is apt to sag unless well supported, and is easily injured by external pressure, blows or the gnawing of rats. Its limited use may also be partially accounted for by the fact that it is relatively expensive. For waste pipe, lead is admirably adapted because it corrodes very slowly and is not readily affected by chemical action.

BRASS

Brass pipe is probably the best service pipe obtainable. The reason for its limited use lies in the fact that it is quite expensive.

Brass pipe posseses all the desirable features found in the other service pipes, coupled with great durability. It is extremely valuble as a conveyor of hot waters, since they do not attack the pipe, and corrosion takes place very slowly. If used only in the hot water system, brass pipe is to be recommended.

WROUGHT IRON AND STEEL

Wrought iron and steel pipe differ in their chemical makeup, but on the market the terms are often used synonomously. In ordering wrought iron pipe it is, therefore, well to specify "genuine wrought iron."

Wrought iron and steel pipes oxidize very rapidly and therein lies their chief disadvantage. Much experimental work relative to the comparative rate of corrosion of the two metals has been carried on. It is the consensus of opinion among those who have made extensive tests that wrought iron does not corrode nearly as rapidly as steel under ordinary service conditions.

Zinc coated or galvanized pipe, under average conditions, will undoubtedly give longer service, since the zinc forms a protective covering which retards the rate of deterioration. All factors considered, however, the best service pipe for farm use is galvanized wrought iron pipe. The advantages are that it will withstand pressure, is easily put together, is relatively cheap, and reasonably durable, making it an economical pipe investment.

SIZE OF PIPE TO USE

Since the smaller the pipe, the greater the friction, thus decreasing the pressure, and since in the smaller sizes of pipe obstructions of rust are more apt to occur, it is well to get a pipe of fair diameter even though the initial cost is slightly increased. The amount of head and the distance water is to be piped are also factors to be considered. For an average installation, however, an inch or inch and a quarter pipe will prove much more satisfactory in the long run than the smaller sizes.

FRICTION IN PIPES

Account must always be taken of the friction in the pipes, since this one factor alone will often determine the successful operation or the failure of a pump, ram, or water system.

Table 4 gives the friction loss in head for the commoner sizes of pipe. These figures are of value in working out numerous piping problems. They also show clearly why the larger sizes of pipe are necessary where the water has to be piped long distances.

For example, assume that water is to be piped from a spring 500

TABLE 4.—Friction of Water in Galvanized Pipes*

Discharge Gallons per Minute	Friction Loss in Feet per 100 Feet of Pipe of Various Diameters in Inches				
	½ In. Diam.	¾ In. Diam.	1 In. Diam.	1¼ In. Diam.	1½ In. Diam.
1	5.50	.80	.20	....	....
2	....	2.50	.80	.20	....
3	....	5.50	1.60	.40	....
4	....	9.00	2.75	.80	....
5	....	14.00	4.25	1.20	....
6	....	.....	6.00	1.60	.60
7	....	.....	8.00	2.00	.80
8	....	.....	10.00	2.50	1.00
9	....	.....	13.00	3.25	1.30
10	....	.....	.....	4.00	1.60
12	....	.....	.....	5.50	2.25
15	....	.....	.....	8.50	3.50

*Adapted from tables compiled by the Rural Engineering Department, Cornell University.

feet away from and 40 feet above the house, and a discharge of 5 gallons per minute is desired. If a ¾ inch pipe were installed, there would be a loss of head, due to friction, of 70 feet. With a 1 inch pipe this loss in head would be 21 feet, and with a 1¼ inch pipe, the loss in head due to friction would be reduced to 6 feet. This illustrates that in the case of the ¾ inch pipe the system would not work, as desired, while with the 1 inch or 1¼ inch pipe the results would be very satisfactory.

It should also be remembered in installing the pipe, that the fewer the bends, the less the pressure is affected. Consequently, effort should be made to have a minimum number of elbows in the pipe.

Plumbing Equipment

In planning the installation of a water system, the question always arises as to just what kind of equipment to buy. Consequently, a brief discussion of the kinds, and costs, of the various items of equipment may aid in formulating the decision.

There is such a wide range in the kinds of equipment available that one may be largely guided by personal choice within the limits of the pocketbook. It is, however, false economy to purchase cheap equipment, from the standpoint of durability, satisfaction, and appearance.

THE KITCHEN SINK

Many types of sinks are available for use in the kitchen, and at prices ranging from about three dollars to sixty dollars. This makes it possible to install a three dollar sink and a fifty cent drain board, or something more costly up to an enameled iron sink and drainboard combined, with white enameled back. All serve the same purpose

but from the standpoint of the housewife, some type of enameled sink is to be preferred. It is much easier to keep clean, presents a much neater appearance, and adds a tone of sanitation and cheerfulness in the kitchen which offsets the slight additional cost.

LAUNDRY TUBS

When running water is available an investment in tubs into which water can be run and from which it can be drained, without the use of hand labor, is worth while. The tubs may be made of wood, slate, or enameled iron. Although wooden tubs are cheap and can be made at home, they will give off disagreeable odors after a time because of the absorbtion of organic matter. Slate tubs, a set of two, can be purchased for from $25 to $35. The chief advantage of enameled tubs over slate is their appearance, and the cost is about three times as great.

BATH TUBS

One of the most difficult cleaning tasks in the household is cleaning under and behind the bathtub. For this reason a "built-in" enameled tub is to be preferred as it fits snugly into the corner of the room and eliminates the necessity of cleaning beneath and behind it. It also presents a much cleaner, neater appearance. Any enameled tub, however, is much to be preferred to the tin-lined tub of the type common a few years ago, and will cost from $20 to $100.

WASH BASIN AND WATER CLOSET

The wash basin should be of enameled iron and of a type to correspond with the style of the other bath equipment purchased.

The most satisfactory style of water closet is either the syphon or syphon-jet closet. Their advantages over the other types lie in the fact that they are more sanitary, quieter, and there is less likelihood of disagreeable odors.

ARRANGEMENT

The plumbing should all be arranged around a single soil stack and all items of equipment should be provided with traps in order to make a tight seal for the prevention of odors. The soil stack should be of cast iron and not less than four inches in diameter, with the joints tightly calked with lead and oakum.

In installing equipment in the kitchen, care should be taken to locate it so that the work can be done with the greatest economy of effort. Definite suggestions in regard to kitchen arrangement may be obtained by writing the Agricultural Extension Division, College of Agriculture, Morgantown, West Virginia.

Circular 45 January, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

Roadside Marketing for West Virginia Farmers

The Successful Roadside Market Depends on Repeat Sales. Attractiveness of Display and a Quality Product Are Essential Factors in Obtaining This End. The Volume of the Commodity Will Attract the Attention of the Prospective Buyer.

By
W. W. ARMENTROUT

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

SUMMARY

1.—Improved roads in West Virginia have brought an opportunity to several farmers for disposing of their farm products direct to the consumer through Roadside Markets.

2.—Fruits, vegetables, poultry and eggs, butter, canned fruits, jellies, sandwiches, and soft drinks are the best sellers through the Roadside Market.

3.—The best location for a Roadside Market is on a slight grade or at the top of a hill. At the bottom or on the side of a hill, on a curve or behind anything which will obstruct the view of the motorist is a poor location.

4.—In general the best returns have come to Roadside Markets when the price asked is somewhere between the city wholesale and retail prices. It appears to be poor business practice to ask city retail prices for products offered for sale at a Roadside Market. The smaller volume of business resulting from such a price policy will mean smaller net returns to the enterprise.

5.—Advertising may be used very effectively in attracting customers to the Roadside Market.

6.—It is good business practice to grade and maintain a high standard for all products offered for sale through the Roadside Market.

7.—An attractive display is an important factor in effecting sales.

8.—Attendants should be neat and clean, and the premises should be kept clean and attractive.

9.—It seems desirable that a large part of the products offered for sale should be produced locally.

Roadside Marketing for West Virginia Farmers

A roadside market is a stand along a road where a farmer offers his farm products for sale direct to the consumer. The stand may be a permanent building, a temporary building, or merely tables or benches on which the products are displayed.

The two most important considerations in contemplating the establishment of a roadside market are to have something to sell which the consumer wants and to have a sufficient number of consumers passing who may be induced to stop and make purchases.

It is only in recent years that West Virginia has "come out of the mud" in so far as road construction is concerned. Most of the improved roads in the state have been built during the past five years and still more recently have our larger cities been connected with hard surfaced roads. Hard surfaced roads lead out in several directions from each of the larger cities of the state. There are sufficient through roads to attract many tourists, and many people who live in the towns and cities make short drives into the country. Travel over the highways has increased enormously during the past two years, and as connecting links and roads already planned are completed there is promise of a still greater increase in highway travel. There seems little doubt but that there are a sufficient number of consumers traveling some of the highways to justify a few attempts at roadside marketing.

For a long while it has been necessary for the farmer to take his product to the consumer. It was on rare occasions only that the city consumer travelled far into the farming sections. But now hundreds of consumers pass by farms each day. They consume the kind of things, often the very products, grown on the farms which they pass but which have been marketed through the regular channels. Why then should they not buy direct from the farmer?

Roadside marketing, for the present at least, offers an opportunity in marketing for only a few of the more enterprising farmers who live on the more travelled roads and who are in a position to produce commodities which the consumers want. To be more specific there appears to be an opportunity for success in the undertaking along the various roads leading out of Wheeling, Huntington, Charleston,

---

The picture on the front cover of this circular and the one on page 5 are printed through the courtesy of the University of Maryland, Agricultural Experiment Station.

Parkersburg, Clarksburg, Morgantown, Fairmont, Bluefield, Martinsburg, and possibly some of the other towns of the state.

This kind of marketing does not hold out much promise to the vast majority of farmers as a means of disposing of their products, but for those few who are fortunately located there does appear to be a real opportunity for marketing direct to the consumer.

Commercial people have seen the opportunity for highway marketing, and along the more travelled roads of the state soft drink stands, barbecue and lunch stands, and filling stations have taken over many desirable locations. From all apperances many of these stands seem to be doing a fair volume of business. It is true that these stands appeal to a somewhat different sort of trade than would a roadside market. It is not to be expected, however, that a roadside market would attract the majority of travellers, but for its business must depend on selling to a minority of those who pass.

For West Virginia, roadside marketing will be a new venture, except in a few sections, but it has been tried for several years in the neighboring states of Maryland, Pennsylvania, New Jersey, and Massachusetts, as well as in other sections of the United States. Both the farmers and consumers in West Virginia are in a position to profit by the experiences which our neighboring farmers have encountered in such a marketing enterprise. This circular is an attempt to present something from the experiences of other states which may be of value to those who desire to undertake roadside marketing in West Virginia.

Kind of Products to Offer For Sale

Fruits and vegetables of various kinds, potatoes, live and dressed poultry, eggs, butter, canned fruits, jellies, ice cream, sandwiches, in fact most any kind of food commodities which the farmer and his family can produce may be offered for sale and find an outlet through the roadside market. In connection with the above things a gasoline filling station might be operated, and also candies, tobacco, and soft drinks sold.

Of course, this sort of marketing will not take care of the disposal of products such as grain, hay, and livestock. A trade might be built up, however, for such products are dressed meats and sausage. It is desirable that a market specialize along a certain line so as to build up a reputation for a few products, but it is a good practice to carry a variety of things so as to have a sufficient volume of business to warrant the operation of the market.

Location

The best location is where the road is level, on a slight grade, or on the top of a hill. The stand should not be located along the side or at the bottom of a difficult hill. The motorist likes to make the hill in high gear and will probably pass by a stand thus located expecting to find one where stopping and starting is easier. The stand should be located where it can be seen at a considerable distance. This gives the motorist time to make up his mind to stop. If other circumstances make it necessary to locate the stand on a curve, sign boards should be placed along the highway some distance away from the stand to notify the motorist that he is approaching a roadside market. This will offset in some measure the effect of a poor location.

This Roadside Market is at a Disadvantage Due to Being Located on the Side of a Hill. Experience Has Shown That the Ideal Location is at the Top Rather Than at the Bottom or on the Side of a Hill.

It is not best to locate the stand behind a bank or any other obstruction, which prevents the motorist from seeing it before he reaches it. A shady location is very desirable since it will appeal to the motorist on a hot summer day. It is best that the market be located several feet away from the edge of the highway and easy approaches onto the highway provided so that cars can easily get off the road. It is desirable to have a driveway and a parking space to accommodate several cars. A gravel driveway will keep the automobile out of the mud and will keep down the dust in dry weather.

The stand should not be located so that a traffic congestion will

result from motorists stopping to make purchases. It should not be located opposite a white line placed on the road by highway officials nor on a narrow road where traffic is congested, unless it is well off the highway. There is danger of accidents from such locations, and a few accidents will probably call forth restrictive measures from highway officials.

A stand may be located on a side road off of the improved highway, but obviously, it will require more extraordinary methods to draw trade to one so located than to one located on the highway. Every disadvantage in location must be made up for in better advertising, more attractive stand, higher quality of offering, or more favorable prices.

Type of Market

The type of building is probably the least important factor contributing to the success of a market. It certainly cannot be ranked in importance with the service, the quality, grade and pack of the offerings, and the price.

There are many ways in which farm products may be displayed. The simplest way is to arrange them on stands or benches or even on

One of the Simplest Types of Roadside Markets. The Display Could Be Improved. Placards, Showing the Price and Telling That the Commodities Are for Sale, Would Prove of Value in Disposing of the Products.

the ground, with a sign indicating the price and that they are for sale. The other extreme is a rather expensive building kept open the year around and employing one or more attendants. Some of the more pretentious markets have wide driveways, ample parking space, and provide rest rooms for the convenience of their customers and the traveling public.

The type of market should depend on the quantity of products the farmer expects to offer for sale and the length of the season he expects to operate it. If there are only small quantities to be offered for sale at intermittent periods it would hardly pay to invest in a building. On the other hand if the farmer expects to sell more or less regularly over a period of four to six months it would be desirable to invest in an inexpensive building. A very desirable type of building is one in which a part of the walls is on hinges and can be opened, making shelves on which to display the product. The farmer should select a type of building which he can best afford. It is desirable to start in a simple way and expand and make improvements as success in the business warrants.

The Price to Charge

From a study of Roadside Markets in Maryland, the report of which was published as University of Maryland Agricultural Experiment Station Bulletin No. 280, the authors give the following pertinent advice concerning the prices to be asked for products sold through roadside markets.

Price is the greatest factor of all in control of sales. Much attention should be devoted to the question of prices and how they affect sales. Many persons desire to buy at the roadside market because of the possibility of securing fresh farm produce at reasonable prices. Prices should be reasonable, considering the quality, grade, and pack, and the fact that the consumer is buying at the point of production and doing his own cartage. The trouble encountered is that producers selling on the road often over-reach the mark by charging city prices, thus keeping for themselves all the saving made possible rather than dividing with the roadside buyer. Generally it is not desirable to charge the full retail price, as the retailer sells and delivers on a charge account. There is a very decided feeling that prices should be somewhere between city wholesale and retail prices. It must be remembered that in the long run a large volume of sales at lower prices brings greater returns than fewer sales at higher prices. * * * The grower who charges too much will lose his trade just the same as will the man in any other merchantile business. * * *

Prices that should be charged at roadside stands with respect to city prices would vary, of course, with the kinds of products sold. There is such a demand, particularly during certain seasons of the year, for such products as strictly fresh eggs, fresh farm-dressed poultry, etc., that such farm products of good quality should command high prices at roadside stands.

Advertising

Advertising is a very important factor in drawing trade to the roadside market. Bulletin boards announcing prices and special products for sale; well worded posters, neatly printed and placed in prominent positions along the highways; hand bills announcing that certain

This is a Combination Roadside Market and Lunch Stand. Most of the Things Sold Through This Market Came From the Farm of the Owner. The Building is Rather Expensive. More Attractive Signs Could Be Used to Advantage.

commodities are in season, mailed to prospective customers; short advertisements in local papers; all are excellent means of calling the attention of the consumer to the stand. The farmer should study various means of advertising to secure the best methods suitable for his local conditions.

Grading and Standardizing

It is most important that the products offered for sale be well graded and the standard maintained. The success of the stand will depend on repeat orders and constant repeat orders come only when the consumer is satisfied that he will get goods of the same high quality each time he comes to the stand. Customers often make a special trip for purchases, but if they cannot count on finding what they want

when they reach the stand they will not make the effort to go to that particular stand. No business can be built up on such uncertainty.

The farmer may sell his low quality product but it should be carefully graded from his quality product and displayed in another part of the stand.

To get repeat orders, the farmer must be honest, giving honest weights and measures, and putting up an honest pack. A few purchases in which good apples are on top of the basket and inferior apples out of sight; good berries on top and poor berries in the bottom; a short bushel, or a container not well filled, and a customer is lost. Not only is one customer lost but he becomes a knocker instead of what might have been a booster.

Value of Display

The products should be neatly arranged, and both products and premises kept clean, neat, and attractive. The general appearance of the products, the stand, and the premises as well as of the attendant has much to do with attracting customers to stop. A great variety of products should be offered for sale and in sufficient volume to attract the attention of the traveller. The consumer has a feeling that he can come nearer getting what he wants if he has considerable volume from which to make his selections.

A Combination Roadside Market and Soft Drink and Lunch Stand. A Substantial Building, But Not Well Adapted for Displaying Farm Products. Little Attention Has Been Paid to Advertising Features.

The Attendant

The stand may be operated by any member of the family. If the business is small it is not necessary for an attendant to be in charge all the time, but means for calling the attendant should be provided, and he should be ready to answer such calls from customers. The attendant should be neat and clean for this is nothing more than a factor in good salesmanship. It is often quite practicable for a child to attend to the selling, but older persons, if tactful, stand a better chance of building up a business.

Sell Locally Grown Products

It seems desirable that a considerable portion of the products offered for sale be locally grown. When shipped-in products are handled to any extent there is nothing to distinguish the roadside market from the regular grocery store, and it is doubtful if shipped-in products can be handled through a roadside market at a worth while profit; that is, if the majority of the business is done in such products.

Dairy Products Are Sold Direct to the Consumer at This Farm. The Owner Caters to the Tourist Trade.

Where one farmer does not produce a sufficient quantity or variety of products to justify the operation of a market, it would be a good plan for some few farmers to sell their products through one market. One farmer could be put in charge of the market and the others deliver their products to him. One large market would be

better and more economical in operation than several small ones. A suitable location could be selected, there would be ample quantity and variety, there would be business enough to justify a permanent building, advertising, and a full time attendant.

Circular 46

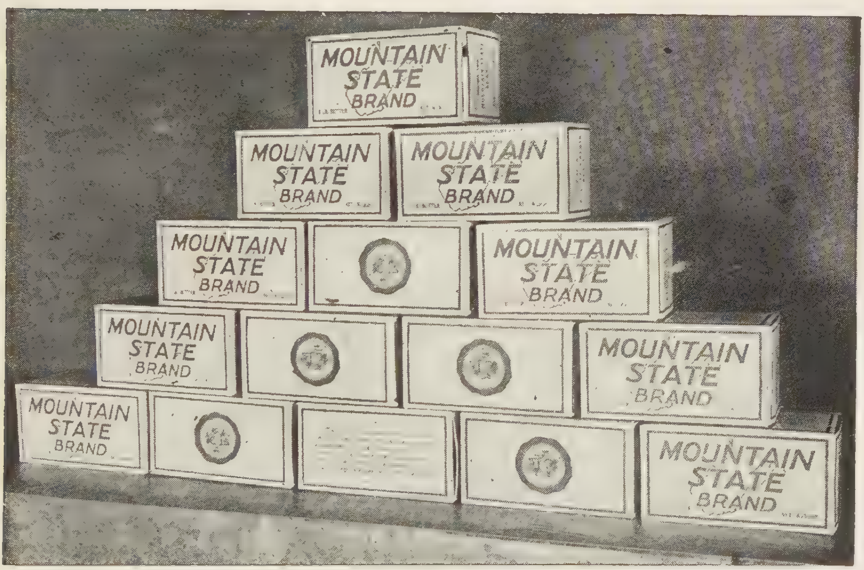
May, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

BETTER FARM BUTTER



"Mountain State Brand" is a Guarantee of a Quality Product.

By
G. MALCOLM TROUT and JAMES V. HOPKINS

Steps in Making Good Farm Butter

1.—Churn cream that tests at least 30 per cent.

2.—Ripen the cream until thick at 68 to 70 degrees Fahrenheit

3.—Wash, scald, and cool the churn and all equipment before churning.

4.—Use a barrel churn. More butter is obtained and the churning process can be kept under control.

5.—Strain the cream into the churn.

6.—Use a churning temperature that will bring the butter in a firm condition in from 30 to 45 minutes. This will be about 58 to 60 degrees Fahrenheit in the winter and 52 to 54 degrees during the summer. Buy a good dairy thermometer and use it.

7.—Add butter color during the late fall and winter; 20 to 30 drops per gallon of cream will be sufficient to produce a "June" color.

8.—Stop the churning process when the butter granules are of the size of wheat or corn grains. Never churn so long that the butter comes in one large lump.

9.—Wash out the buttermilk, with water tempered the same or slightly colder than the buttermilk, instead of working it out; buttermilk is responsible for many off flavors and mottles.

10.—Salt the butter when it is in a granular form with a good grade of butter salt. Hard dry salt dissolves with difficulty and should not be used.

11.—Work the salt thoroughly into the butter. The body and texture of the butter should be firm and waxy when sufficiently worked. Over-working produces a sticky, pasty body and is responsible for rapid deterioration.

12.—Mold the butter in rectangular pound prints rather than in the round form. Wrap in parchment paper and store where cool. Paraffin cartons should be used to protect the parchment and keep the butter from dust and dirt.

13.—Wash all the utensils thoroughly using a good washing powder instead of soap. Rinse with hot water and allow to dry in the sun.

BETTER FARM BUTTER

According to the latest reports available, West Virginia produces annually approximately 18,000,000 pounds of country butter. All the butter made on the farms is not sold, of course, but the income of most of the general farms in the state is augmented by the sale of butter in varying quantities.

During the past five years the Dairy Department, College of Agriculture, West Virginia University, has scored several hundred samples of farm butter, representing practically every county in the state. The scores of this butter and the criticisims noted indicate that a large proportion of West Virginia's farm butter is of inferior quality. The redeeming feature of the scoring contests has been the possibility of improvement of quality through the adoption of improved methods. Most of the "off flavors" found in this butter could be eliminated entirely by improving some of the steps in butter making.

The purpose of this circular is to give directions for improving the quality of the butter being produced on the farms in West Virginia, rather than to increase the quantity produced.

Higher quality and better prices go together. The amount of variation in the price of farm butter in the state is only exceeded by the variation of the quality of the butter made. Butter is sold on a very definite basis of quality which must be increased before a higher price for farm butter can be obtained. With the introduction of roadside marketing, home industries shops, Mountain State Brand of butter, and the parcels post system for better distribution, wonderful opportunities are offered the farm women for selling butter at an attractive price. But in order to create a demand and secure repeated sales, the butter must be of exceptional quality and be the same week after week. By following the steps outlined herein, a general improvement of quality may be secured and uniformly maintained.

Necessary Equipment

The making of good farm butter does not require elaborate equipment but depends more on the methods than on the equipment used. Necessary equipment for making high quality butter includes a floating thermometer, a triangular butter worker, a stirring rod, strainer, shotgun can, two pails, two wooden paddles or ladles, a rectangular butter printer, scales, parchment wrapping paper and car-

tons, a stiff fibre scrubbing brush, and good washing powder. The accompanying picture illustrates the best types of equipment for making butter on the farm.

The churn is of the most importance in butter making equipment. There are several kinds of churns on the market, each having its advantages and disadvantages.

THE DASH CHURN

The dash churn is used quite extensively throughout West Virginia. This is probably the least desirable type of churn that could be obtained. First, the up and down agitation with the dasher involves much labor. Maximum agitation cannot be obtained which means that a long churning period will be required. During churning some of the cream splashes up onto the handle and the lid and remains there without being churned. Furthermore, all the cream is not agitated evenly. These factors cause a high fat loss in the buttermilk, which means a low yield of butter.

It is difficult with the dash churn to stop the churning process at the proper time, that is, when the butter granules are of right size. Usually the butter comes in lumps in which stage it cannot be washed properly. Most of the dash churns are narrower at the top than at the bottom which makes the removal of the butter somewhat inconvenient. Another disadvantage of the dash churn is that the butter cannot be washed in the churn but must be removed and washed where it

Good Equipment for Making Butter on the Farm.

is exposed to the air and in such a way that it is difficult to remove all the buttermilk.

THE SWING CHURN

The swing churn has several advantages over the dash churn. However, it is harder to keep clean and in a sanitary condition, because of the angular corners. There is not so great a loss of fat in the buttermilk and hence a greater yield of butter is obtained. Maximum agitation is secured with the swing churn only when the churning is being done with a rapid, vigorous stroke. In this churn all the cream is forced to one end where it splashes back over to the bottom of the other end. The course taken by the cream is similiar to the figure eight. If the speed is slackened the agitation will be greatly reduced which means longer churning.

THE BARREL CHURN

The barrel churn has almost universal use and meets the requirements where butter is made on a small scale. It is the best type of churn obtainable. There are two kinds of barrel churns in common use to-day, the steel churn and the wooden stave. The steel one has the disadvantage that, since steel is a good conductor of heat, the cream will warm up considerably during churning and the butter may come soft. The steel churn, however, has the advantage over the wooden one in that it will not dry out and become leaky, when not in constant or regular use.

Maximum agitation and more complete churning can be secured in the barrel churn than in most other types of churns. Every particle of cream is agitated evenly which means that the size of the butter granules can be controlled. They will be of an even size and the churning process can be stopped with the assurance that none of the granules will be so small that they will pass out with the buttermilk.

The barrel churn has a vent or opening at the bottom through which the buttermilk and wash water may be drawn. This is a decided advantage in eliminating the handling of the butter during washing. The butter can be easily washed in the churn thus keeping it away from exposure to the air and also making it possible to wash out all the buttermilk.

Ripening the Cream

High quality cream is the first essential in making a high quality butter. It is impossible to produce the highest grade of butter from inferior quality cream. The making of high scoring butter really begins

with milking the cow, cleaning the utensils, and handling the cream. These factors have been discussed fully in Circular No. 43, entitled "Producing Cream on the Farm," and will not be discussed further here. Copies of that circular may be obtained by writing to the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

As a general thing those who have a large number of cows and churn frequently produce the highest quality of butter. This is because the cream is churned while fresh and has not developed any flavors injurious to the sweet, creamy flavor common to high scoring butter. When cream is held for a long period of time, even at a low temperature, an old stale flavor develops which is hard to keep out of the butter.

The idea is prevalent that cream must be sour to churn. This is not true as sweet cream churns readily and the butter made therefrom is of exceptional quality. It does, however, lack in flavor, being somewhat flat and having little aroma. The American public demands butter that is high in flavor and aroma. Such butter is made from slightly sour cream. In the creamery this souring or ripening is under control at all times. The ripening of cream should be controlled on the farm as nearly as possible as it is in the creamery.

TABLE 1.—Temperatures for Ripening Cream.

Season	Per Cent Butterfat	Temperature to Ripen	Temperature of Cream for Churning
March	25	70	56 to 58
to	30	68	54 to 56
June	35	67	54 to 56
June	25	67	54 to 56
to	30	67	52 to 54
November	35	67	50 to 52
November	25	68	58 to 62
to	30	68	57 to 60
March	35	70	55 to 58

"Souring" of cream is the changing of milk sugar to lactic acid. Tiny organisms called bacteria bring about this change. Temperatures greatly influence the rapidity of bacterial development. Various numbers of different bacteria are always present in cream. These develop their best at specific temperatures. Many of these bacteria act upon the milk sugar and bring about a souring, but only a few strains are responsible for the clean, mild acid flavor of the butter.

These particular strains of desirable bacteria grow best at 68 to 70 degrees Fahrenheit. A higher temperature than this will retard their development and favor the development of the undesirable types. When the cream is to be ripened it should be well stirred and placed in an atmosphere about 70 degrees Fahrenheit. The best temperatures for ripening cream are shown in Table 1.

The cream previous to churning should be handled in one of the following ways:

First Method.—Cool all cream as received to 50 degrees Fahrenheit or below, and keep it as cold and sweet as possible until enough has been secured for churning. Then stir thoroughly and raise it to the temperature of from 68 to 70 degrees Fahrenheit. Keep it at this temperature until it is sour enough to churn (usually 18 hours is long enough); cool to churning temperature; hold for two or three hours; then churn.

Second Method.—Warm the first gathering of cream to 70 degrees Fahrenheit and hold it at this temperature until it is slightly sour; cool as cold as cellar or spring house temperature; hold at this temperature and add, after cooling, each succeeding batch of cream to it, stirring each time. When enough has been secured for a churning, it will usually be sour enough to churn. If not, warm up to 70 degrees Fahrenheit and hold until sour; then cool to churning temperature; hold for two or three hours; and churn.

Third Method.—Add one quart of **good, clean clabber or buttermilk** to the first gathering of cream. Stir, set at cellar or spring house temperature, then add each successive batch of cream after cooling, and proceed as in the second method.

At the proper degree of ripeness the cream will appear shiny, thick, and will not be foamy and wheyed off as is the case when overripened. These methods of ripening cream on the farm have no equals. Never set the can of cream behind the stove for ripening unless this is necessary to give the desired temperature.

If starters are to be used they should be propagated separately through skim milk, and added directly to the cream at the time of ripening rather than saving buttermilk from each churning. One cup of good starter to every two gallons of cream should be sufficient. Pour the starter into the cream and stir well when the cream is brought into the ripening room. Cultures can be had from various dairy supply houses. Directions for propagating starter usually accompany each culture.

Preparing the Equipment

Just previous to churning, the churn, worker, printer, and ladles should be washed thoroughly to remove all dust and dirt which may have accumulated since the last churning. If the churn and equipment were washed properly at the close of the previous churning little scrubbing will be necessary. Use a washing powder and rinse it off with cold water. Then soak all the equipment in scalding water for about five minutes. Immediately following this rinse and soak the same utensils in cold water. The paddles and printer should remain in the cold water until ready for use. The hot water opens the pores of the wood which are filled and closed when soaked in cold water. This procedure prevents sticking of the butter in the churn and on the paddles and worker during working and printing.

Adding Butter Color

Only during late fall and winter will it be necessary to add butter color. The market demands a light yellow-colored butter. When the cows have access to pasture, the butter fat will have sufficient color.

During the late fall and winter when dry feeds are fed, the cows cannot get enough of this coloring matter from their feed to impart a rich golden yellow to the fat. At this time it is necessary to add a small amount of a good color to the cream just previous to churning. The coloring is a vegetable product and does not injure the butter in any way. The amount of color used varies with the time of the year and the strength of the color. The maker must use judgment as to the amount to use. The important thing is to maintain the same color in the butter throughout the year. In winter the quantity required to produce the desired shade of yellow ranges from 20 to 30 drops per gallon of cream. When measured in a teaspoon this amount is from a quarter to a half teaspoonful. The color should always be added just previous to churning.

Temperature and Time of Churning

The more important factors which influence the temperature at which to churn are, season of the year, stage of lactation, and feeds fed the cow.

No definite churning temperature can be given which will be suitable for all times. A person must use judgment as to the best temperatures for producing a firm body of butter knowing fully the factors involved. The best churning temperature is that which will require from 30 to 45 minutes to churn. The resulting butter should be fairly hard and firm. When the butter comes in this condition, the size of the granules can be controlled and the buttermilk can be washed out easily. Furthermore, the salt can be worked in well without injuring the body of the butter. Butter that comes soft and slushy is full of buttermilk and will have a greasy and weak body after washing out the buttermilk and working in the salt. Butter is often churned at too high a temperature. This may cause rapid deterioration of the butter due to the presence of excess buttermilk.

The best churning temperature for the winter months is 58 to 60 degrees Fahrenheit while 52 to 55 degrees will be suitable temperatures for churning during the summer. These may need to be varied a few degrees to suit best the conditions of particular herds and stages of lactations. The hardness of the fats alone will determine largely the correct temperature. Cows on pasture and green feeds produce milk with a higher percentage of soft fat hence the necessity of lowering the churning temperature during the summer. The opposite is true during the winter. Cottonseed meal is known to produce hard fats while linseed meal produces soft ones.

As a cow advances in her lactation period the fat globules become harder and smaller. When all the cream is from such cows it is necessary to raise the churning temperature a few degrees if the butter is to come within a reasonable period of time.

Cooling Cream Before Churning

When the cream is cooled from 70 degrees Fahrenheit to churning temperature and churned immediately the butter will come very soft and in about the same condition as though it were churned at 70 degrees. Although the thermometer shows that the cream itself has cooled to the proper temperature, the tiny fat globules are yet warm. It requires about two hours for them to cool down to the temperature indicated by the thermometer. Therefore, always hold the cream about two hours at the churning temperature before beginning the churning.

Straining the Cream into the Churn.

Never put ice directly into the cream to cool it to the proper temperature for this causes a tallowy body in the resulting butter. Set the can of cream into another can of cold water until the cream comes to the right temperature. Ice may be placed in the outer can if necessary. Changing the cooling water frequently will hasten the cooling. Stir the cream vigorously at intervals while cooling.

The Churning Process

The churn should be prepared for churning by being thoroughly washed, scalded, and cooled before placing the cream in it. The cream should be strained into the churn to remove possible heavy lumps of curd. A 20-mesh seive dipper has been found to be very satisfactory for this. The churn should never be filled more than one-third to one-half full.

The churn should be turned fast enough to get the greatest amount of concussion within the churn. With the barrel churn this will be about 45 to 55 revolutions per minute· Turning too slowly results in the cream flowing around the sides of the churn with little agitation. On the other hand, too rapid churning results in the cream clinging to the sides of the churn without any concussion whatsoever.

When churning first begins the cream will swell and it will be necessary to let the gas or air escape. Turn the churn up two or three times at intervals of a few minutes, open the vent in the bottom of the churn and allow the gas to escape. This will not be necessary after the first few minutes of churning.

As the churning progresses the cream will foam and finally whip up not unlike whipped cream. When in this condition, it will be necessary to slow down the churning or else the cream will cling to the sides and move with the churn without any agitation. When the cream becomes thick during churning it is about to "break," or in other words, "the butter is about to come." When the peep glass first becomes clear stop the churn, take off the lid, and examine the butter. The granules should be about the size of wheat or corn grains. Notice on the lid whether there are any tiny butter particles. If there are any very small butter granules present the churning is not completed, but will require another revolution or two. **Above all else discontinue the churning process before the butter collects into large balls in which condition the buttermilk cannot be washed nor worked out.** Even overworking the butter later which brings other very undesirable results, will not get all the buttermilk out once the butter is churned into large balls.

Churning Incomplete; Granules Not Yet Well-Formed

Proper Stage at Which to Stop Churning; Granules About the Size of Corn Grains.

Over-Churned; Granules Compacted into Large Balls. In This Condition the Buttermilk Cannot be Washed Out Thoroughly.

Washing the Butter

Good butter cannot be produced unless the buttermilk is washed out of the butter completely. Buttermilk contains the milk sugar and casein, both food for bacteria. If this food supply for the bacteria is eliminated it is obvious that the bacterial growth will be greatly retarded. Many of the "off" flavors of butter, such as rancidity, and sour butter are due to the presence of buttermilk in the butter. Furthermore, mottles and white specks in butter are the result of buttermilk together with uneven distribution of salt.

There is but one way to get the buttermilk from the butter and that is to wash it out. When the churning process has been stopped with the butter granules the size of wheat grains this can best be done. Fasten the churn upright, open the vent and draw off the buttermilk through the strainer· With plenty of wash water previously tempered to the temperature of the cream or one or two degrees colder than the buttermilk, flush down the sides of the churn and the butter with a couple of quarts of wash water. After this has drained out close the vent and add to the churn about as much water as there was buttermilk. Churn not more than five revolutions. Drain this off and, if the wash water is very milky, repeat the same process using the same amount of wash water.

Washing is not intended to harden the butter. The hardness has been already determined by the churning temperature. Should it be necessary to harden the butter somewhat before working this should be done gradually by placing the butter in water a couple of degrees colder than the butter rather than by adding ice water to the churn. Ice water applied directly to soft butter causes it to become brittle and thus injures the firm waxy body.

Only clean, pure, water should be used in washing the butter as the butter will take up and retain part of the impurities of water, if any are present.

Salting and Working the Butter

Entirely too much of West Virginia's farm butter contains undissolved salt and is criticized for being "gritty". This does not mean that too much salt is used, but rather the wrong kind of salt was used or the salt was not worked in suffícently.

After the butter is taken from the churn and placed onto the triangular-lever butter worker, salt should be sprinkled on it at the rate of one-third to three-fourths of an ounce of salt per pound of butter. Only clean dairy or butter salt free from lumps should be used. This dissolves readily and does not impart a bitter taste to the butter.

In Working Butter, it Should be Pressed with a Firm Stroke of the Lever. Avoid Sliding the Lever which Smears the Butter.

Ordinary table salt should not be used for salting butter, as it sometimes contains an insoluble substance which appears in the butter as "grittiness". Furthermore table salt is hard to dissolve because the grains of salt are hard and dry. A little cold water splashed over the butter after it has been salted and before working will hasten the dissolving of the salt.

Butter is worked to bring the granules together into one firm body, to remove the excess moisture, and to distribute the brine and salt evenly. Butter is never worked to get the buttermilk out, for by proper churning and washing this has already been eliminated. With the sharp edge of the lever turned downward press the butter with a firm stroke. Raise the lever, move it over one or two inches and press another section of the butter. As soon as all the butter has been worked over once, gather the butter together into another ball and press out as before. Avoid sliding the lever or smearing the butter during working as this will cause the butter to become greasy and salvy. When the butter is free from holes, firm, and no gritty salt can be found by rubbing a small peice between the fingers, it has been worked sufficiently.

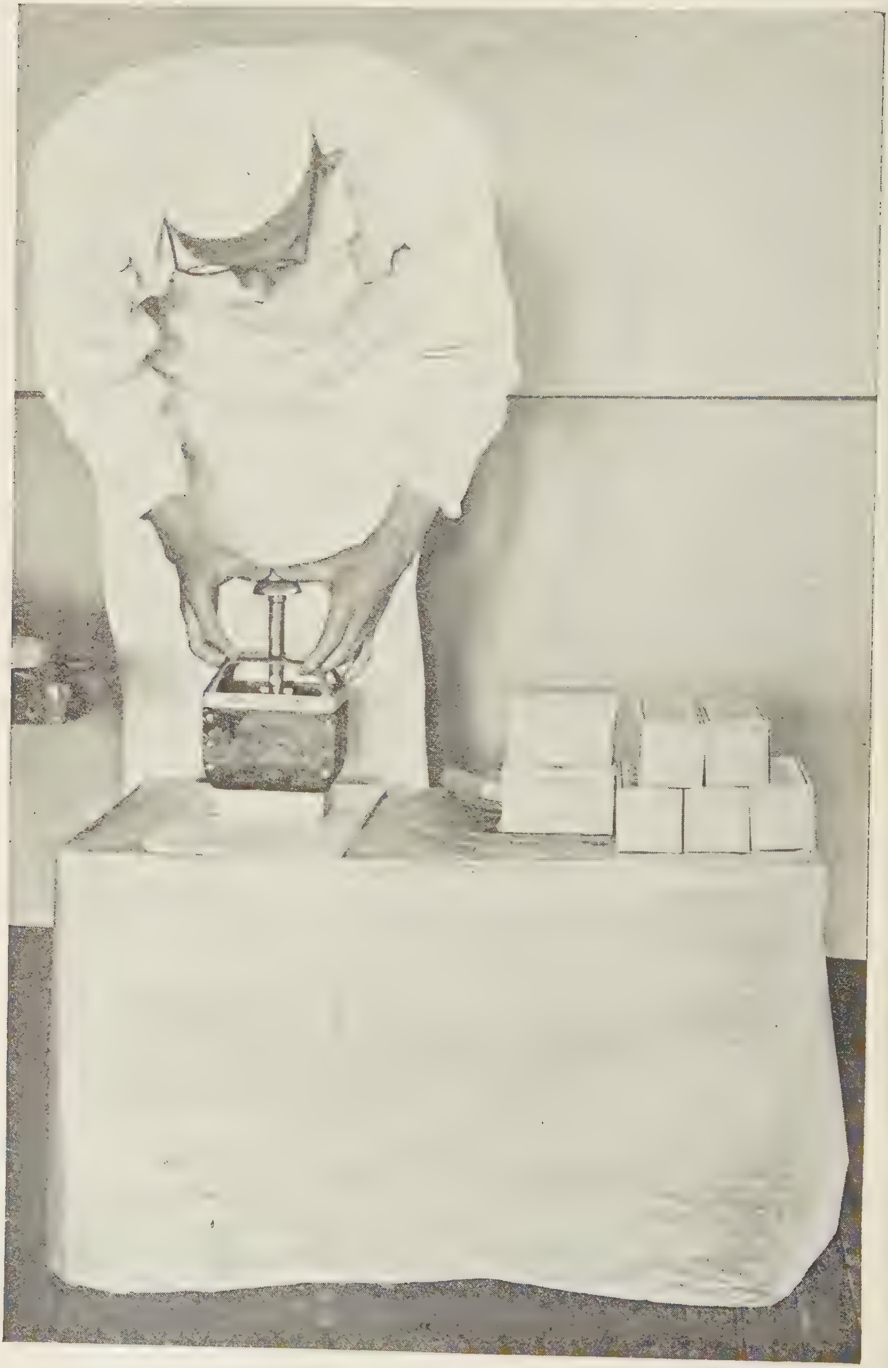
More than 75 per cent of the farm butter can be criticised for being mottled. These mottles are the result of the presence of buttermilk and the uneven distribution of the salt. These faults can be avoided by proper and thorough removal of the buttermilk and by sufficient working. In case they occur, however, they can be eliminated by allowing the butter to set two hours after working and then reworking before printing and packing.

Printing and Packing

In order to market butter to the best advantage it should be put up in one pound prints, preferably of the rectangular type rather than in the round prints. The public has come to associate the round print with a poor quality butter and will not pay as much for it as for butter in the brick shaped molds. Furthermore, it is harder to wrap and package round prints than it is the rectangular ones.

The finished package of butter should be neat, clean, and furnish an attractive appearance. Butter wrapped in an oil paper does not present a very pleasing appearance after it has been handled a few times as is necessary when the package is shipped through the mails. The same is true of butter wrapped in a cloth.

Parchment paper, eight by eleven inches, furnishes the best wrapping for butter. This paper may be secured from any dairy supply house either plain or with the maker's particular trade mark printed



The Rectangular Mold Makes a Neat Package Which Helps to Increase Sales.

on it. The cost will be less than $2.00 per 1000 sheets. Waxed cartons made expressly for the rectangular one pound prints can be obtained also from the same dairy supply house. The cost for the first 1000 will probably be about $7.00. The maker's trade name can be printed on the cartons the same as on the parchment papers. By the use of these papers and cartons the total cost of packing one pound of butter is less than one cent. When butter is packed in this manner the consumer will gladly pay several cents more per pound for it, because he instinctively knows that the maker took just pride in its manufacture and in seeing that the butter reached him in a standard attractive package which protected it from dust and dirt.

The parchment papers may be either wet or dry when wrapping the butter. To secure the neatest package, however, the paper should be dry. With the butter heaped up on the worker, press the printer down upon the roll firmly until the printer is well filled. Cut off the excess butter with the sharp edge of the paddle. Grasp the filled printer with both hands, hold it directly over the center of the parchment and press out the butter. Weigh this print to make sure it weighs a full pound. It may be necessary to make some adjustments in the printer to insure delivery of a full pound. Pull up one end of the paper and smooth it out upon one side of the print. Press the edges down the sides, then roll the print over one turn and press the edges down as before. Continue this until it comes to finishing the wrapping when the ends should be tucked under instead of being pressed down the sides. When the package is viewed from the end, all the corners of the paper should meet directly in the center and form a neat package. The wrapped print should be placed immediately in the carton and set in a cool place until disposed of.

When butter is to be salted down for winter use, two wrappers should be used instead of one. The butter should be packed in cartons as usual and placed in a saturated brine solution contained in a stone jar. Place a brick on top to hold the packages down and cover the jar to prevent evaporation. Butter thus put down will keep in good condition for several months.

Washing the Equipment

Rinse all the utensils first in lukewarm or cold water to remove the cream, buttermilk, and particles of butter, and then wash them in warm water containing a good washing powder. Use a stiff fibre scrubbing brush and scrub every inch of surface thoroughly, noticing particularly that no butter or buttermilk remains. Do not use a cloth about the churn or any of the churning equipment. Since a cloth

does not dry out readily, foul odors will develop. These odors will remain on the churn and wooden equipment if a cloth is used. The fibre brush has the advantage that it dries quickly and is open so that the air can get to every part. Soap should not be used to wash dairy utensils where the highest quality product is to be made as it leaves a film of soap and grease on the surface. Washing powder, which is largely soda, dissolves all the grease and is easily rinsed off.

When the utensils have been washed thoroughly, rinse them off in hot water and set them aside to dry. Never wipe them dry with a cloth, but keep the cloth away from the equipment entirely and let the utensils drain and dry of their own accord. If the rinse water was hot enough and applied the proper length of time the heat will be sufficient to dry them. To keep the utensils sweet and clean, exposing them to the direct rays of the sun for an hour or two is indespensible. If they are not to be used for some time, they should be placed after drying in an airy place free from dust. Above all else keep the utensils sweet, clean, and free from foul odors.

How to Overcome Difficult Churning

At some seasons of the year churning is accomplished with great difficulty. Even after hours of churning no butter appears. Instead of continuing to churn, the factors responsible for the difficulty should be studied and remedied. The following are generally responsible for the difficulty:

1.—The churning temperature is too low. Raise the temperature to 60 degrees Fahrenheit in the winter and to 50 to 54 degrees Fahrenheit in the summer.

2.—The churn is too full for proper concussion. The churn should never be more than one-half full. Slightly more than one-third full is the proper amount.

3.—The cream is either too thin or too rich. A 30 per cent cream is a desirable richness for churning.

4.—The cream is too viscous. Ripen the cream until it is thick. Ripened cream is thick but brittle and does not cling to the churn as rich sweet cream does.

5.—The cream is in a ropy condition which prevents it from being agitated. This is a bacteriological problem and may be solved through proper sterilization of all utensils, and by keeping the cows away from marshes and stagnant pools, or by draining the pools, as this particular organism thrives in such places.

6.—The cows are in an advanced state of lactation. About the only remedy is to add some cream before ripening from a cow re-

cently fresh. Churn at a higher temperature.

7.—The fats are too hard. Some feeds, such as cottonseed meal, produce a larger proportion of hard fats. If this is fed to cows during advanced lactation the difficulty of churning is multiplied. Not only are the fat globules small, but hard as well. Linseed meal, silage, and succulent feeds counteract this difficulty. It will be necessary to use a higher churning temperature when cows are fed on feeds which produce hard fats.

Scoring Butter

Butter is scored on five main divisions; namely, flavor, body, color, salt, and package. Flavor, of course, is the most important, and of 100 points on the score card, 45 points are allowed for this particular thing. Body is given 25 points, color 15 points, salt 10 points, and package 15 points. There is no butter made which scores perfect for then our ideal of perfection will have been reached. Most butter on the market to-day scores betwen 83 and 93. A score of 90 or above is very good. Butter scoring below 90 can easily be improved in quality by checking the defects and changing the methods of manufacture.

Butter usually scores between 30 and 40 points, out of a possible 45, on flavor. Scoring butter for flavor involves taking a piece of butter into the mouth, melting it against the palate, and noting the

Packages of Butter Sent to Dairy Department, West Virginia University, by West Virginia Farm Women to be Scored in the 1926 Butter Scoring Contest.

flavor and aroma. The flavor should be sweet, clean, and have a pleasant aroma. Body scores between 23 and 25 out of a possible 25 and should be firm and waxy to score perfect. A piece of good butter broken across appears jagged and rough as broken iron. It never strings out.

Salt, package, color, and body are determined through the senses of sight and feeling. Color scores from 13 to 15 out of a possible 15. No cuts in score are made as a rule when the butter is even in color Mottled and wavy butter are seriously discriminated against. Butter usually scores perfect in salt unless the salt is in an undissolved form, in which case one or two points are taken off. The package, if neat and clean, is usually scored perfect.

BUTTER SCORE CARD

Flavor	45	Clean, sweet, flavor; pleasing aroma. free from any objectional taste or smell. (Forty points under this head is a very high score. Much of the best grade of creamery butter will not score over 37 to 38 points.)
Body	15	Grain firm, waxy, smooth. (Butter may be cut several points on flavor yet score perfect on body. Butter showing poor body is cut from 2 to 5 points. Slight defects are cut 1 to 3 points.)
Color	15	Even, free from mottles or streaks. (Degree of color to meet market demands, bad defects in color often cut 1.5 to 2 points.)
Salt	10	Well dissolved. (Amount of salt somewhat governed by market demands. A cut of .5 to 1 point may be made if butter is very gritty or has excessive amount of salt.)
Package	5	Neat, clean, and well put up.
Total	100	

The Mountain State Brand for Butter

The Mountain State Brand was established to improve the general quality of farm butter through repeated scorings and to insure consumers against inferior quality product. Those who have taken advantage of the use of this brand have succeeded in securing from ten to fifteen cents more per pound for their butter than they were receiving for ordinary farm butter.

Farm butter makers in West Virginia can market their butter under this brand by applying to the Agricultural Extension Division, and meeting the following requirements:

1.—Each person is required to send, so as to reach the Extension Division of West Virginia University by the fifteenth of each month, a one-fourth pound sample of average butter from every churning until such time as their butter reaches the score of 90 points, and once per month thereafter.

2.—The samples will be scored by the Dairy Department of West Virginia University and a report made, together with instructions as how the product can be improved.

3.—With each sample sent in, a report on how the butter was made is required on an entry blank furnished for this purpose by the Extension Division of the College of Agriculture at Morgantown.

Specialist Scoring Butter in the Laboratory.

4.—When the butter of any member reaches the score of 90 points or above, his or her name will be placed on the butter honor roll.

5.—Members of the honor roll will be entitled to receive the special one-pound "Mountain State Brand" cartons similar to those shown in the picture on the front cut. These cartons will be furnished at cost (about 1½ cents each) and will bear a printed statement as to the high quality of the butter. The purchaser of this "Mountain State Brand" will thus be assured of obtaining a high class product.

6.—If in any month the member's score does not reach 90 points, another sample will be required at once and if it does not come up to the standard the member will be prohibited from using the "Mountain State Brand" cartons until his product again reaches the required score.

7.—Each member will be assigned a certain number and this number will be stamped on all the cartons supplied her. In this way any poor butter sold in such cartons may be easily traced back to its maker; and anyone found using the "Mountain State Brand" cartons when not entitled to do so, will be prohibited thenceforth from the use of them entirely.

Mountain State Brand Butter is butter of a standard quality and is becoming well known on the markets in West Virginia. The fact that quality in butter counts is shown by the ready sale of Mountain State Brand Butter in different parts of the state at prices ranging from 10 to 20 cents higher than the average price of farm butter.

It will pay any farm butter maker who does not have a satisfactory market to investigate this plan.

Circular 47

June, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director,
Morgantown

PASTURE IMPROVEMENT

A West Virginia Pasture Scene

By
T. E. ODLAND, R. J. GARBER, and D. R. DODD

SUMMARY

1.—On most West Virginia farms one of the chief sources of cash income is derived directly from the pasture.

2.—Pastures throughout the state are generally in a very low state of productivity.

3.—Pastures in West Virginia may be classed roughly into three groups: (1) Those pastures that may be plowed and reseeded; (2) those that are too steep to make plowing practicable but are capable of producing profitable pasture; and (3) those that are too steep and rough to make it advisable to attempt to improve them. Pastures of this last type should be put back into timber.

4.—The chief causes of the low carrying capacity of our pastures are: exhausted fertility; overgrazing, especially early in the season; and allowing weeds and briers to grow unmolested.

5.—Plowing, liming, fertilizing, and reseeding are recommended except where land is too steep to make this practicable. Lime and fertilizer may be applied as a top dressing where the land is too steep to plow. Such practice is most profitable when accompanied with a light harrowing or disking.

6.—Pastures should periodically be given lime and fertilizer treatments.

7.—A preliminary trial on a small typical area may be advisable in order to determine whether a certain treatment will yield satisfactory returns on any particular farm.

8.—Where pasture is to be provided as part of a regular crop rotation the seed mixtures used will depend upon the location, type of soil, and kind of rotation followed.

9.—Oats and peas make one of the best combinations for providing a temporary early spring pasture.

10.—Sweet clover provides excellent temporary pasture under many conditions in the state.

PASTURE IMPROVEMENT

On most of West Virginia farms one of the largest items in the cash income of the farmer is from the sale of livestock. Probably 95 per cent of this livestock is sold directly from pasture rather than from the feed lot. Pasture, therefore, is a very important item in determining the amount of the farmer's cash income.

More than one half of the improved land included in the farms of the state is devoted to pasture and, due to topography, cannot be brought into general crop production. Consequently, the future of most of West Virginia farms is to be determined to a very large extent by the future of their pastures.

For many years there has been a gradual falling off in the productiveness of pastures. New pasture land will generally produce sufficient grass to carry one 1000-pound animal for each 2½ to 3½ acres. A pasture that will do this is commonly spoken of as a "good pasture." The tendency toward lower production has continued until today an average of four or more acres are required to graze a 1000-pound animal for the season.

During this same time there has been a steady rise in the cost of maintaining pastures. The cost of fence and of keeping the pasture clean are higher than at any previous time. These two opposite tendencies—lower production and higher cost—have brought about a condition in which the average pasture produces almost no net profit.

Since any great reduction in the costs is impossible the average livestock farmer of West Virginia is face to face with the proposition of improving his pasture or going out of business.

Fortunately, pasture experiments at the West Virginia Agricultural Experiment Station and pasture demonstrations on farms in many sections of the state, give conclusive proof that many now unprofitable pastures can be brought into the profitable group again. This can be done with a smaller amount of capital than is usually supposed.

All permanent pastures may be roughly divided into three groups. The first group includes those pastures sufficiently level to permit reestablishing by plowing. The second group includes those too steep to re-establish by plowing, but not too steep to get over with liming machinery and a harrow. The third group includes those unproductive lands suitable primarily for timber production. The best and most

profitable crop that ever came off this land was the timber and the sooner it goes back to timber the better it will be.

CAUSES OF POOR PASTURES

Three things are largely responsible for our present poor pastures. These are unproductive soil, overgrazing early in the season, and weeds and briers. These will be considered separately.

Exhausted Farm Land

Many of the old pastures in the state are farm lands that were once cropped but were abandoned for that purpose when it was found unprofitable to use them for cultivated crops. They were then fenced off for pasture with no further provision for the maintenance of their productivity. No satisfactory pasture can be established on such land until its productivity has again been built up. The pasture must be considered as a field producing an annual crop just as much as a field in a cultivated crop and its maintenance must be provided for accordingly. Experiments conducted by a number of experiment stations have shown that an acre in good pasture will yield as great or even a greater profit than an acre in many other crops on the farm and with much less outlay in time and money.

A typical sample of pasture on land that was once cropped but has been abandoned because of low productivity. A satisfactory pasture can not be established on exhausted farm land until its fertility is restored.

Over Grazing

Many pastures in the state are injured and kept in a low state of productivity by over grazing early in the season. Often the livestock is turned onto pasture long before the grass has had an opportunity to get started in the spring and then allowed to keep the grass so closely grazed all season that it has no opportunity to get established. A pasture can often be greatly improved by keeping the livestock out until after corn planting time. By that time the pasture usually has a good start.

The nature of the sod will determine to a large extent how heavily a pasture may be grazed without injury. Results obtained in experiments made at the Virginia Agricultural Experiment Station,* indicate that a good heavy blue grass sod is benefitted by being fairly closely grazed throughout the season. On many farms in West Virginia, however, there is more danger from over-grazing than from under-giazing pastures. Over-grazing during the early spring, especially, should be avoided.

Weeds and Briers

It is very evident that many pastures in the state could be con-

A pasture showing a rank growth of filth. Weeds and briers should be kept cut in the pasture.

*Virginia Agricultural Experiment Station, Bul. 204, 1917.

siderably improved by cutting the weeds and briers once or twice during the season. The most effective time to do this is just after the spring and early summer growth has exhausted the reserve food stored by the plants during the previous year. This ordinarily means about the middle of June in West Virginia. If the pastures are cut over at that time and, if time permits, again later in the summer when the new growth has come on, the amount of weeds and briers will soon be much reduced.

A method sometimes used effectively in getting rid of filth in a pasture is to cut the briers and weeds thoroughly once and then graze it closely with cattle or sheep for several years. If the new growth can be kept down in this way it will serve the same purpose as repeated cuttings. This is also an economical way of clearing land that is to be used later for growing crops.

In clearing land for pasture it is well to remember that no grasses or clovers grow well in the shade. The more open the pasture is, the better the chances of getting a good sod. A few trees should be left, however, to provide shade for the livestock.

PLOWING AND RESEEDING OLD PASTURES

Where the land is not too steep and it is otherwise practicable

A bluegrass pasture with limestone outcrop. A few trees should be left for shade as shown in this pasture scene.

to plow and reseed an old run down pasture, this is by all means the best method of rejuvenating it. By plowing the land and cropping it for a year or two an opportunity is afforded to eradicate many weeds that are usually found in such pastures. Liberal quantities of manure, if available, or a green manure crop and also lime and fertilizer should be incorporated in order to build up the fertility of such land before reseeding it for pasture.

Time to Plow

Probably the best time for plowing up old pastures will be late in the fall or early in the spring. Such land can usually be plowed when other fields are too wet to work. Late spring plowing is apt to leave the ground too loose to make a good seed bed for grass the first year.

Lime and Fertilizers

Lime and phosphate are essential in any soil improvement program in West Virginia. These may be applied either in the fall before the land is plowed or in the spring before the crops are planted. As an average application about two tons of crushed limestone or its equivalent in other forms of lime and three hundred pounds of acid phosphate per acre are suggested. If nitrate or a complete fertilizer carrying considerable soluble nitrogen is used, the application should be made in the spring when the land is seeded.

Reseeding

If it is desired to reestablish the pasture as quickly as possible grass may be seeded in the spring following plowing. As a nurse crop oats is suggested. The seeding should be made as early in the spring as possible. In order to give the grass a better opportunity the oats should be cut early and used for hay. It is a good practice, where possible, to crop the land for several years before reseeding, as this gives a better opportunity to build up the productivity of the land to a point where a good stand of grass may be obtained.

Grass Seed Mixtures

The kinds of grasses to be used in reseeding, or establishing pastures for the first time, varies with the type of soil. For example, on good clay soils bluegrass does exceptionally well, while on light sandy soils red top is much more dependable. A mixture of several kinds of grasses and legumes, however, usually gives better results than a seeding of any one alone.

This should not be interpreted to mean the more species of grasses the better, for usually only a limited number will survive in a certain soil type. It has been found that it is usually a better prac-

tice to determine what kinds of grasses are the most likely to survive and then to sow more of these per acre rather than a complex mixture of many kinds of seeds. A study of the grasses in old, well established pastures in the vicinity will usually prove a good guide as to what kinds will probably survive the best.

On productive land, or land that can be built into a good state of productivity, Kentucky bluegrass and white clover should be the chief ingredients of any mixture. These plants require about the same amount of liming as does red clover. Kentucky bluegrass and white clover make an ideal pasture and where these can be sucessfully grown there is not much need of others. Two or three years are usually required for a bluegrass pasture to get well established. Ordinarily therefore, some more rapidly growing grasses are seeded in the mixture to produce either hay or pasture while the bluegrass and white clover are becoming established.

Much of the hilly land in West Virginia is too poor to support a good bluegrass sod. On such soils Canada bluegrass and redtop will probably do better. As in the case with the more productive soils it is advisable to use more rapid growing grasses and clovers in the mixture in order to produce hay or pasture while the slow growing grasses are getting established.

It is desirable to add orchard grass to almost any pasture mixture on account of its early spring and late fall growth. This grass will also thrive on much poorer and more acid soils than will timothy or Kentucky bluegrass.

In making up the suggested grass seed mixtures two soil types have been taken into consideration. One set of mixtures will be found best suited for a fairly productive soil or one that can be made so by the application of lime and fertilizers. The other set of seed mixtures is best suited to an acid soil low in fertility such as is often met with in the state. For each of these conditions two mixtures are suggested—one where the crop is to be used for hay for a year before the land is left for pasture and the other mixture is suitable where the pasture is to be established as quickly as possible without using it for hay for one or more years. The seed mixtures given herein are suggested for the foregoing conditions. The number of pounds of each recommended is enough to make up the seed needed for one acre.

1. For productive soils with a hay crop preceeding pasture.

Timothy	6 pounds
Red clover	6 pounds
Kentucky bluegrass	4 pounds
Orchard grass	2 pounds
White Clover	2 pounds
	20 pounds

2. **For productive soils with no hay crop preceeding pasture.**

Kentucky bluegrass	10 pounds
Timothy	4 pounds
Orchard grass	2 pounds
Alsike clover*	2 pounds
White clover	2 pounds
	20 pounds

3. **For poor soils with a hay crop preceeding pasture.**

Orchard grass	8 pounds
Tall oat grass	8 pounds
Alsike clover	4 pounds
Canada bluegrass	4 pounds
Redtop	2 pounds
White clover†	2 pounds
	28 pounds

4. **For poor soils with no hay crop preceeding pasture.**

Canada bluegrass	10 pounds
Tall oat grass	6 pounds
Orchard grass	6 pounds
Redtop	2 pounds
Alsike clover*	2 pounds
White clover†	2 pounds
	28 pounds

In the last two mixtures suggested tall oat grass is substituted for timothy, and Canada bluegrass for Kentucky bluegrass. Where lime and fertilizer are applied, the land, although poor to begin with, may often be built up to a state where the first two mixtures may be used. Kentucky bluegrass makes a more satisfactory pasture grass than Canada bluegrass and should be used wherever possible.

For unproductive wet land the last two mixtures may be used, but the tall oat grass which is not adapted to wet soils should be omitted.

Treatment After a Pasture Has Been Established

After a permanent pasture has been established it should be considered as a field producing a crop just like any field that is in a cultivated crop. Recent experiments conducted by the Pennsylvania Agricultural Experiment Station** have shown that an acre in good bluegrass pasture may yield greater returns than an acre of similar land in a four year rotation of corn, oats, wheat, and hay. In order to keep up the productivity of the pasture an application of about a ton of pulverised limestone or its equivalent should be ap-

*On limed soil 4 pounds white sweet clover may be used instead of the Alsike.
†Japan clover may be substituted for part of the white clover in these mixtures.
**Pennsylania Agricultural Experiment Station, Bul. 195, 1925.

plied every four to six years and either acid phosphate or a complete fertilizer applied every three or four years. The amounts of fertilizer to apply and the frequency will depend upon the productivity of the soil.

IMPROVING PASTURES WITHOUT PLOWING

Many pastures in the state are too steep or rough to make plowing practicable. Of these some are too poor to make them worth attempting to improve. Other pastures which are too steep for plowing may profitably be improved by treatment. Experiments at the West Virginia Station and demonstrations previously referred to, indicate that generally the best treatment consists of harrowing, together with the application of lime and fertilizers.

Many West Virginia pastures are too steep to plow.

Liming

Nearly all soils in the state would be benefitted by an application of lime. The kind of lime appears to make little difference. One ton of pulverized limestone, 1480 pounds of hydrate lime, or 1120 pounds of burnt lime have about equal neutralizing power. Where the land is very low in fertility the benificial effects of lime will not be as marked as on more productive fields. An application of phosphate together with the lime will usually produce very striking results on a pasture. In experiments conducted by this station on typical hillside pastures, the yields of grass have been increased from four to six times by the application of two tons of limestone and 300 pounds of the acid phosphate per acre. When land is top dressed in this way with lime the effects will not be evident as quickly as when applied to plowed ground. An application of one ton of lime-

stone every fourth to sixth year after the initial treatment is recommended for most pastures of the state.

Fertilizer Application

In nearly all cases liming the land should precede fertilizer application or be applied at the same time. Applications of acid phosphate alone have given considerable increases of grass yields on experiments conducted at this Station but the increases have been much greater where both lime and phosphate have been applied. The lime is necessary to put the land in such a state that the phosphate can exert its greatest influence just as phosphate or other fertility treatments are necessary to bring out the best results from lime application.

Although phosphate is usually the most essential fertilizer for land in West Virginia, experiments on meadows and pastures have indicated that on many soils a complete fertilizer will yield even greater returns per dollar expended. A complete fertilizer with a relatively high percentage of nitrate usually will produce a greater yield of hay or pasture. For such purpose a 6-8-4 fertilizer is recommended.

Fertilizers containing nitrogen should be applied in the spring. Acid phosphate may be applied in the spring or fall. Phosphate does not leach out of the soil as does nitrate.

Manuring

The application of farm manure together with lime and phosphate has yielded the greatest returns in grass in the pasture experiments at this Station. Applying manure as a top dressing to a pasture is a very effective way of improving it, wherever this can be done.

Seed Application

Scattering seed over an old pasture without any other treatment is in nearly every case a waste of time and effort. In experiments conducted by the West Virginia Experiment Station no improvement whatever resulted when seed was applied without the addition of either lime or fertilizer. Where there is not enough fertility in the soil to support a grass crop it is useless to apply seed only.

Where the lime and fertilizer have been applied as a top dressing to a pasture, seed mixture number 2 as given on page 9 is recommended. The seed should be applied in the spring and barrowed in. In some pastures where there is already a fairly good stand of bluegrass, no seed will be necessary. The fertilizer and lime treatments will enable the existing sod to thicken up and make an excellent pasture.

Disking and Harrowing

Where possible the land should be disked lightly after it has

been treated with lime and fertilizers and reseeded. The disking will help to incorporate the lime and fertilizer with the soil and cover some of the seed. The disking should not be heavy enough to tear up the sod and cause washing of the soil. Although disking or harrowing is recommended, the other treatments should not be witheld because it is not practicable to disk the ground. Excellent results have been obtained with many pastures where no cultural treatment followed the lime and fertilizer treatments.

Pasture Demonstrations

Where one is in doubt as to the advisability of going to the expense in time and money of undertaking to improve a pasture by the application of lime and fertilizers it may be advisable to make a preliminary trial of a small typical area of the pasture. By making such a preliminary test one can usually determine whether it will be profitable to undertake similar treatments for the entire pasture. The following plan for such a demonstration is suggested:

Acid phosphate and seed (Plot 1)	Acid phosphate lime and seed (Plot 2)	Lime and acid phosphate (Plot 3)
Seed only (Plot 4)	Lime and seed (Plot 5)	Lime only (Plot 6)
Complete fertilizer and seed (Plot 7)	Lime, complete fertilizer, and seed (Plot 8)	Lime and complete fertilizer (Plot 9)

Each plot according to the foregoing plan or diagram should be 25 feet wide and 50 feet long, thus making the total area required for the nine plots 75 feet by 150 feet.

To apply the treatments, drill the acid-phosphate at the rate of 300 pounds per acre over the upper strip consisting of plots numbered 1, 2 and 3. Leave the next 25 foot strip (plots 4, 5, and 6) without fertilizer treatment. On the lower strip (plots 7, 8, and 9) drill the complete fertilizer at the same rate as the acid phosphate on the upper strip. About 25 pounds each of phosphate and complete fertilizer will be required for this demonstration.

The lime should next be drilled at the rate of two tons of limestone per acre over the area of plots 2, 3 5, 6, 8, and 9. Approximately 750 pounds of limestone will be required. If there is no drill available, the lime and fertilizer may be applied by hand.

Next seed the area consisting of plots 1, 2, 4, 5, 7, and 8 with

4 pounds of one of the seed mixtures recommended for seeding a pasture that has not been plowed.

After the lime, phosphate, and seed treatments have been applied the whole area should be disked or harrowed lightly if the land is not too steep or rough to permit this.

The plots should be set off with substantial stakes that will remain in place for several years. These plots will enable one to note the effect of these treatments either alone or in combination. This plan can be modified in any way to meet the individual requirements.

TEMPORARY PASTURES

On many farms in the state it is necessary to provide a certain amount of pasturage in addition to that provided by the permanent pastures. In some cases this may be provided by planning for a certain amount of pasture in the regular rotation of crops while with others the problem is to furnish supplemental pasture during the "short pasture" season of midsummer. In other cases the problem is to provide for a temporary early spring pasture that can be used until the grass can get a start in the permanent pasture.

Pastures in the Crop Rotation

On many farms it is advisable, if not necessary, to devote one or more years of the crop rotation to pasture. This is a very common practice in the Eastern Panhandle, especially in Berkeley and Jefferson counties, and in the Northern Panhandle. Where this practice is to be followed the rotation and crops should be chosen accordingly. The following are some of the suggested rotations in which pasture is provided:

Five Year Rotation

First year.—Corn, seeded at last cultivation with one bushel of rye and twenty pounds of vetch per acre for early spring pasture the next year.

Second year.—Soybeans, for hay or seed.

Third year.—Wheat, seeded to clover-grass mixture.

Fourth year.—Clover-hay; the second crop may be pastured.

Fifth year.—Clover and grass, for pasture.

Manure should be applied on pasture for the next corn crop.

The following meadow mixture for a field later to be pastured one year is suggested: 5 pounds red clover, 3 pounds alsike clover, 8 pounds timothy, and 4 pounds red top per acre.

Four Year Rotation:

First year.—Corn.

Second year.—Wheat or oats, seeded to clover-grass mixture.

Third year.—Hay.

Fourth year.—Pasture.

With this rotation the same mixture of grass and clover may be used as suggested for the five year rotation.

Three Year Rotation:

First year.—Corn.

Second year.—Wheat or oats, seeded to clover-grass mixture.

Third year.—Pasture.

In this three year rotation of corn, small grain, and pasture, the seeding of pasture grasses and clover may be made in the grain as is usual with meadow seedings. A suggested mixture consists of the following:

White sweet clover	6 pounds per acre
Red clover	4 pounds per acre
Alsike clover	2 pounds per acre
Timothy	5 pounds per acre
Redtop	3 pounds per acre
Total	20 pounds per acre

Where the pasture is for dairy cattle and the land is known to be adapted to sweet clover, more of this may be used and the other clovers and grasses decreased.

Modified Rotation

Frequently it is advisable to hold a rotation pasture two or more years. This may be done in any of the foregoing cases by adding six pounds of Kentucky bluegrass and two pounds of white clover to the seed mixture mentioned. In rotation pastures four important items should be kept in mind.

First—Consider the pasture crop as removed the same as other crops in other years.

Second—Provide additional fertilizer and manure for this pasture crop.

Third—Provide one or more legumes in this pasture.

Fourth—Seeds of grasses and clovers suited to pasturing must be included in the seed mixture and heavier seedings made.

Early Spring Pastures

When the feed supply runs low in the spring of the year cattle are likely to be turned on pasture even though the pasture is in no condition to receive them. This is done repeatedly by some of the best dairy and livestock men in the state. It is poor business, but it is also frequently poor business to buy feed. At any rate the cattle are turned out to pasture much too early in the spring. As a result of the grass being eaten off as fast as it grows, the yield of pasture for

the entire year is reduced. The land, pasture, and cattle all suffer.

One solution to this problem rests in our ability to have some special early pasture on which to turn livestock. Since early spring milk production is very important to the dairyman this is probably a more vital need with him than with the livestock man.

For such early spring pasture, three pasture plants are well adapted to West Virginia conditions. These are sweet clover, rye, and vetch. They may be grown in combination or separately. In combination they should be seeded in August at the rate of ten pounds of white sweet clover, twenty pounds of winter vetch, and one bushel of rye per acre. Both legumes should be inoculated. Since the rye and vetch come on more rapidly than the sweet clover, the latter is likely to be damaged by crowding and pasturing. This combination is not to be recommended except where a limited amount of pasture is desired during the fall, early spring, and through the summer. In such cases the combination is very desirable, the rye and vetch providing fall and spring pasture and the sweet clover summer and fall pasture.

A good way to clear land and to keep weeds and briers down in a pasture.

The success of this combination is further dependent upon an abundance of lime to meet the requirements of the sweet clover.

When seeded for fall and spring pasture only, the rye and vetch may be seeded in combination at the rate of 25 pounds of vetch and five pecks of rye per acre in the last cultivation of the corn. This mixture may also be seeded after the corn has been cut or in August and September on especially prepared land.

The sweet clover for the same purposes may be seeded in March or April in oats or other grain and harrowed in or may be seeded in August on a specially prepared seed bed.

It is not ordinarily advisable to seed rye alone. Rye is a rather sure crop but is not a legume and depletes rather than improves a soil. At the same time it furnishes a poor quality of pasture.

Vetch contains a higher percentage of protein than any of our other common legumes. Sweet clover compares favorably with red clover and alfalfa. Dairy cows may be expected to show increase in production of milk when turned from ordinary pasture into either of these. Cattle at first may show a dislike for sweet clover but if turned on when the plants are young they soon acquire a taste for it and further difficulties will not be met.

Sheep, hogs, and horses also do well on these pastures.

Summer Pastures

Among the crops available for summer pasture, especially on dairy farms, sweet clover probably takes first rank. Since this crop has been treated more or less fully under spring pastures it is only mentioned here so that it will not be overlooked.

Occasionally a situation develops where it becomes necessary for the farmer to provide additional pasture for mid-summer when the grass gets short. In such an event small grain crops, Sudan grass, field peas, rape, millet, soybeans, sweet clover, and sorghum have frequently been used. Of these sorghum is the least desirable and should not be used. Millet is only a little better. Rape is very good, but its uses are rather limited. Soybeans are not well adapted to pasturing. Canadian field peas can be grown to advantage only in combination. The other crops mentioned may be grown either alone or in combination. The grains are always available, are cheap, and come on quickly.

Sudan grass produces a heavy growth in mid-season just when badly needed. Sweet clover produces well from mid-summer to fall. Therefore, under conditions of such shortage of pasture, if a quick and continued pasture be desired, a combination is most desirable and the following procedure is recommended: At the earliest possible date in the spring prepare a good seed bed and after an application of lime to meet the lime requirement drill one bushel of Canadian field peas per acre about three inches deep. Follow this with a seeding of six pecks of oats per acre about one to one and a half inches deep. With the oats seeding apply 300 pounds of acid phosphate, seven pounds of Sudan grass, and eight pounds of white sweet clover per acre. The peas and clover seed should of course be inoculated.

This combination will provide an abundance of rich protein pasture from June until late fall. The peas and oats will come on quickly for the first part of the season and the Sudan grass and white sweet clover later and will last until fall. The sweet clover will hold over for further pasture the following season.

Circular 48

September, 1927

Agricultural Experiment Station

College of Agriculture, West Virginia University

HENRY G. KNIGHT, Director
Morgantown

The Care and Management of Sheep

By

C. V. WILSON and J. H. RIETZ

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

SUMMARY

1.—There are conditions in West Virginia favoring increased sheep production.

2.—It is wise for the beginner to start with a relatively small flock of carefully selected ewes and learn the business as the flock is increased.

3.—The ram is half the flock and must be a good purebred for successful production.

4.—Ewes should be treated for parasites, flushed, and tagged prior to the breeding season, and the ram should be fed and cared for so as to be in a vigorous condition.

5.—Community "Ram Days" make for a more uniform lamb crop and promote cooperative marketing. After six weeks the rams should be removed from the ewes.

6.—Bred ewes should be well nourished with a good quality legume roughage and silage, if available, supplemented for about six weeks before lambing time with a suitable grain ration; they should have plenty of exercise in the open, but should be protected by shelter from cold rains and storms.

7.—The shepherd should be ready for the arrival of the first lamb. Individual pens for the ewes for the first day or so after the lambs arrive are a valuable asset. Each ewe should be carefully watched for the first week after lambing and attention given promptly, if needed. Most of the ailments of young lambs may be relieved by simple remedies if given in time.

8.—All lambs should be docked and male lambs that are intended for market castrated when 7 to 14 days old. These operations need not cause any difficulty if properly done, may easily be performed by the flock owner, and pay substantial dividends.

9.—Growing lambs need an abundance of good feed to produce rapid unchecked growth until ready for market. A little grain may often be fed profitably.

10.—The flock owner can increase the value of his wool crop by careful selection of breeding stock, proper feeding, and careful handling of his sheep.

1.—Wool often does not bring full value due to poor shearing and preparation of the fleece. The fleece should be kept clean and tied with paper twine. Shearing should be done as early in the spring as the weather will permit.

12.—Cooperative marketing of both wool and lambs insures a fair return for the product sold and affords the producer an opportunity to learn market demands and the grades that are most profitable to produce.

13.—It is easy to catch and handle sheep, if proper methods are used. Careless handling cuts down the profits to be derived from the flock.

14.—The flock should be carefully culled every year. The best time to do this is before the lambs are separated from their mothers.

15.—It is poor practice and unprofitable to keep cull ewe lambs for the flock. Only the best lambs should be retained.

16.—Parasites are probably the worst enemy of sheep, but may be readily controlled by consistent and properly directed effort.

17.—Sanitation, proper feeding, housing, and care will prevent most of the common ailments of sheep.

The Care and Management of Sheep

STATUS OF THE SHEEP INDUSTRY

The State Department of Agriculture in an estimate released March, 1927, gives the gross income from sheep and wool in West Virginia for 1926 as $3,584,000.00. The estimated wool clip was 2,117,000 pounds, worth $804,000.00. Sales of sheep and lambs were estimated at $2,780,000. On January 1, 1927, the estimates gave 431,000 breeding ewes and sheep, other than lambs, and 78,000 lambs, making a total of 509,000 head of sheep on the 85,000 farms of the state, with approximately 400,000 breeding ewes.

Possibilities of Increase

Conditions at the present time are favorable for an increase in sheep production in West Virginia. Advocates of increased production should bear in mind, however, that such increase should be largely made by experienced flock owners rather than by attempting to start inexperienced men in business. Wool and lambs that are of high quality, uniform in merit, standardized as regards production, and that are systematically and intelligently marketed, are of greater importance than increased numbers of sheep or pounds of wool.

The conditions favoring an increase in sheep production in the state are:

(1) There is a growing demand for uniform, high-quality, standardized West Virginia lambs on the Pittsburgh, Baltimore, and Jersey City markets. Such lambs have frequently topped these markets during the past three or four years.

(2) West Virginia has an abundance of excellent grazing land that is especially suitable for sheep and conducive to the production of early spring lambs. This grazing area consists principally of bluegrass in the limestone hills and valleys of the Appalachian chain of mountains and occupies the larger portion of the entire group of eastern and central counties of the state. The northern panhandle of the state adjacent to Pennsylvania and Ohio is noted for the production of the Delaine Merino and wool growing. (See picture on page 8).

Grand Champion Wether at International Livestock Exposition in 1926. Shown by Pennsylvania State College.

(3) Climatic conditions are such due to the latitude and to the mountainous character of much of the state, that a number of flocks are either never housed or else given shelter for but short periods during the winter months. There is evidence, however, that in most cases, even though shelter is not imperative, the flocks in the state would receive benefit from its more general use.

Points in Favor of Sheep Raising

There are numerous advantages to the farmer in favor of raising sheep. Sheep fit into the general farm plan in such a way that what would otherwise be wasted is converted into salable products. They eat with relish many kinds of weeds that other classes of livestock avoid. While sheep cannot consume very coarse roughage they do thrive on medium pasture and cheap roughage, and except for lambs in the feed lots of the West they are fed very little grain.

Because sheep are light in weight and nimble of foot they are often permitted to graze on land or crops that other livestock would seriously injure. Sheep thrive in steep pastures, meadow aftermath, and growing grain crops. They seldom injure pastures or lots by tramping and usually benefit weedy cattle pastures when limited numbers are grazed along with the cattle.

A Good Type Southdown Ram

A Good Type Shropshire Ram

Sheep do not require as expensive equipment as certain other classes of livestock nor as great initial investment for a foundation flock. They give quick returns, for within a year after the flock has been started they yield two money crops—lambs and wool. Neither of these crops are readily perishable, and it seldom happens that both bring low prices in any one year. When both are low wool may be easily stored and it's sale deferred until prices rise.

Sheep are interesting and attractive to young people, closely approximating poultry in this respect. Four-H Club boys and girls are doing most excellent work with sheep projects in the state. The sheep pay their way and usually yield a profit while the youngsters are learning to improve mutton form, breed type, quality, and fleece. Sheep are gentle and so easily handled that the boys and girls are able to perform practically all of the essential details of care and management.

When sheep are properly managed they are seldom troubled with disease. Tuberculosis is almost unknown, and there is no sickness in sheep comparable to hog cholera. Parasites, external and internal, will utterly ruin a flock, but control methods are so simple, cheap, and effective that no flock need suffer on this account.

A Good Type Hampshire Ram

Problems of Sheep Raising

Sheep raising like other phases of farming has its peculiar problems

or difficulties. The chief ones in West Virginia are:

(1) There is a lack of knowledge of sheep, and of the proper care and management of a flock essential to success. The labor involved in sheep production is no great burden at any time, but constant attention to small details and a knowledge of sheep and their needs are vital to successful production.

(2) Dogs are a constant menace to successful sheep production. In certain sections of the state, even a dog law offers but little help to the sheepman. Only in those sections where sheep are to be found on every or nearly every farm are sheepmen reasonably free from this menace. This is usually due to a community-wide interest in sheep; a sentiment toward the enforcement of the dog law; cooperation of the whole community in tying all dogs from sundown until sunrise; and the use of sheep bells, shot guns, and dog proof fences. A united effort along these lines will usually succeed in establishing a reasonable degree of safety for sheep raising in a community.

(3) Parasites, external and internal, cause far more loss than any other enemy of sheep production. The dog problem is of very minor importance by way of comparison. The parasite works night and day, three hundred and sixty-five days in the year. Relatively few sheep men are aware of the parasites' work until the damage is done. Most flock owners make an attempt once or twice a year to rid their flocks of parasites and then relax their effort. Parasites can be controlled by selecting strong and vigorous breeding stock; providing proper shelter and feed; using dips for external parasites; and giving medicinal liquids, such as copper sulphate, for internal parasites. If in addition pasture can be used in rotation and the lamb crop marketed before August, parasites need not be the cause of great loss.

(4) Poor equipment and management, though easily remedied, are responsible for discouragement and loss in sheep raising. Little or no shelter is provided the flock in winter with very little or no feed other than pasture, and as a result the owner shears a light, weak-fibered fleece and has emaciated ewes that are too thin to properly suckle their lambs. With-

A Good Type Dorset Ram

A Good Type Cheviot Ram

out a pen of some kind it is very difficult to catch sheep, and in case a suitable pen is not provided, the docking and castration of lambs as a rule are not performed, ewes are not kept tagged, and treatment for parasites is not attempted. (See picture on page 9.) Bad fences are responsible for the flock trespassing on growing crops, or on the neighbors, and the sheep are often disposed of to avoid these difficulties.

(5) Market fluctuations in the prices of wool and lambs occur from time to time. Whenever a period of depression comes there are always a number of flock owners who sell out. These same men buy again at about the time sheep and their products have reached the peak price. Experience shows that the flock owner who refuses to follow the crowd usually has a profit for each year over a period of years, while the fellow who is "in and out" generally has alternately a profit and loss. Strong cooperative organizations are an aid and safeguard in securing equitable prices depending, of course, upon the quality of production. Such activities as wool pooling and cooperative shipping of lambs are enabling producers to minimize price fluctuations. These activities serve as a direct means of acquainting the producers with the demands of the market.

ESTABLISHING A FLOCK

Number of Ewes for the Beginner

The inexperienced man starting a flock of grade ewes must decide on the number of ewes for his flock. He should consider the pasture, shelter, and equipment available, and should not undertake to keep more sheep than he can properly provide for.

If suitable equipment and pasture are available, a flock of from fifteen to twenty ewes is a desirable number with which to start. This does not require a large investment and fair profit may be expected. The investment while not large, is enough to direct the attention and

Delaine-Merino Ewes. This Breed is Noted for the Production of Fine Wool and is Popular in the Northern Panhandle of West Virginia.

hold the interest of the new flock owner, and the number is large enough to permit the acquiring of much experience.

A flock of from five to ten ewes may be neglected, does not permit the acquiring of a great deal of experience, or give much profit, and the equipment and shelter is likely to be only make-shift. Since a ram must be kept, the expense for each ewe is from three to five times as great as compared to the ram expense for twenty or more ewes.

It is unwise, however, for the prospective sheep raiser without experience to start with too large a flock. Due to a lack of knowledge and experience disastrous losses may be sustained that are easily prevented after experience has been gained by keeping a relatively small flock.

Selecting Ewes

AGE OF EWES

As a rule the age of sheep may be fairly accurately determined up to four years old by the teeth. A lamb has eight front teeth in the lower jaw. These eight teeth are small and fairly uniform in size. As a yearling the middle pair of lamb teeth are shed and are replaced by a much larger, broader pair. The two year old has two broad pairs; the three year old, three broad pairs; and the four year, four broad pairs.

In sheep that are five, six, or seven years old, and older, the teeth instead of retaining their original broad shape become rounder and shorter, with more and more space between them. If any of the teeth are missing this condition is spoken of as a "broken mouth."

When ewes have badly worn teeth on account of age, or a "broken mouth," they are less able to get food and are more likely to show decline in thrift and vigor. Such ewes should not be purchased by the inexperienced man. Aged ewes can often be purchased at a discount and when given good care they may prove a profitable investment, but as a rule yearling and two year old ewes will give the average sheepman better returns.

WEIGHT OF EWES

Good thrifty young ewes in breeding condition should weigh from 115 to 140 pounds. Ewes much lighter than 115 pounds are likely to be undersized, unthrifty, diseased, and lacking in constitution and mutton form. There is no objection to heavier ewes provided they have good mutton form, and are thrifty and of good quality rather than coarse and slow maturing. Care should be exercised in purchasing extremely fat ewes. Such ewes are often excessively fat because they are barren. It is well to note that large ewes require

Wire Gates Serve as a Convenient Device for Penning Sheep Closely Thus Making It Easy to Catch Them for Shearing, Parasite Treatment, or Other Purposes.

richer feeding grounds than small ewes. Where grazing lands are extremely rough medium-sized ewes are preferable to heavy ones.

UNIFORMITY OF EWES

In so far as it is possible, one should select ewes that are alike in all respects. The lambs from such ewes and out of a good ram will then be more uniform. Where a flock is made up of several colors, sizes, and types of ewes the lambs are not as uniform as is desirable. The wool from such a flock will fall into many grades rather than the few desirable ones.

THE FLEECE

Ewes with dense compact fleeces grading one-quarter to three-eights blood combing should be selected. To grade one-quarter to three-eights blood combing, wool must be fairly dense and at least two and one-half inches long. Approximately one-fourth of the income from the flock is from wool and some attention should be given the fleece. The sheepman in making his selection of breeding ewes will not always be able to select or reject as he would like, but when opportunity offers he will profit by exercising these privileges.

HEALTH AND THRIFT

Ewes that are on fair pasture and appear unthrifty should be

Ewes That Are Alert, Vigorous, and in a Healthy and Thrifty Condition, are Essential to Success.

avoided. They are likely diseased or infested with parasites. Only alert thrifty ewes should be selected. The best ewes are wide and short headed and short and thick of neck. They have wide level backs, well sprung ribs and roomy middles, level rumps, and plump thighs and legs. Their wool is strong and clean. They have wide full breasts and sturdy legs set well apart.

Healthy ewes are alert. Their heads are up at sight of a stranger and they move away with vigor. It is useless to expect profit from unhealthy, unthrifty, or emaciated and disease ridden ewes.

Extremely nervous or wild and foolish ewes should be avoided even though they are thrifty and healthy. They keep the flock in a nervous state. Such ewes are a constant source of trouble in handling and caring for the flock.

THE UDDER

The udder of each ewe should be inspected to see that the teats are pliable. An experienced sheepman can determine whether a ewe has ever had lambs by the udder. Lumps or hard places in udder or teats are likely to cause trouble. Scars about the udder indicate trouble occurring in the past. Ewes with a teat cut off by careless shearing or with only one good side to the udder, should be discarded.

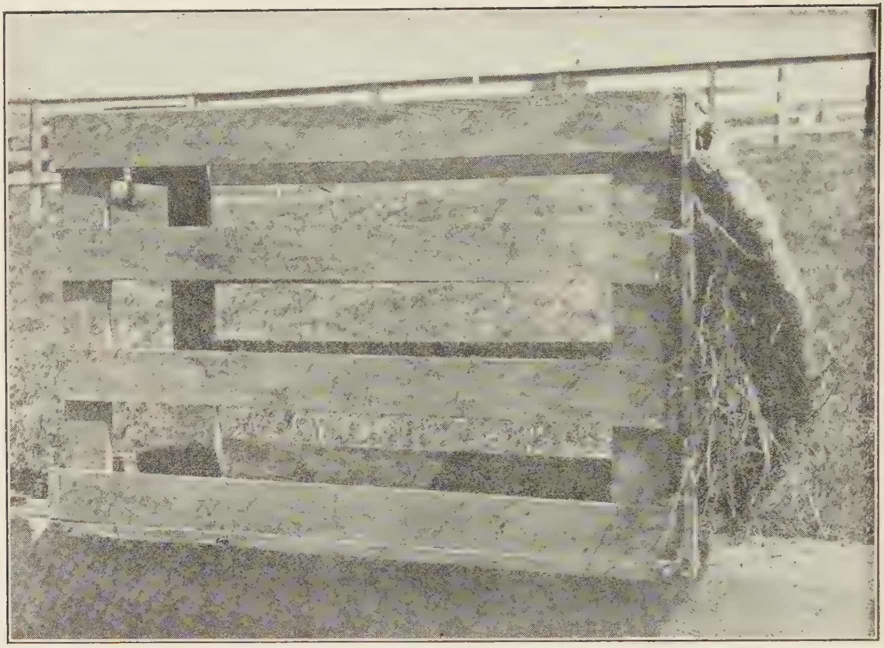
BUYING EWES

Most sheepmen in West Virginia are able to buy the number of sheep they desire within the state. Many times they have opportunity to purchase from their neighbors. In such cases there is an advantage in having the sheep close at hand and in knowing how the sheep are bred, their age, weight, condition, thrift, and other essential factors. Practically all of the flocks in the state are of local origin. A few sheepmen have purchased western ewes through a central market such as Chicago. Such ewes have given equally as good results as native ewes.

In case it is desirable to purchase western ewes, it will be advantageous for several neighbors to cooperate in purchasing a full car load thus effecting economy in freight and commission. Sheep are usually loaded in double deck cars ranging from 100 to 120 medium sized ewes per deck, or from 200 to 240 ewes per car.

Selecting the Ram

If the owner of a grade flock of ewes expects good lambs he will have to select a good ram. If he desires better lambs, than last



A Good Type of Individual Shipping Crate for Ewes or Rams. Note the Height as Compared to Length and the Arrangement on the End for Hay.

year's crop he must select a better ram than he had last year. Should he demand the best lambs, the best ram he can obtain will be necessary.

The selection of the ram is of even greater importance than the selection of the ewes. The ram is responsible for the entire lamb crop of his ewes. A narrow, weak, character-lacking, scrub ram will affect the quality of practically every lamb he sires. Results obtained in experiments at the agricultural experiment stations in Kentucky and Missouri indicate a loss of $3.00 to $3.50 per lamb sired by scrub rams as compared to the lambs sired by blocky, vigorous purebred rams.

Money is lost instead of saved when a scrub or low-grade ram is bought even though he costs less than a purebred. The ram can be an influence for good or bad on all the lambs he sires and that may be as many as 75 lambs. Each ewe has an influence on but one or two lambs. The offsprings of a purebred ram and grade ewe is usually most like the ram.

The ram should be active, vigorous, and bold. He must be mas-

culine and aggressive. His form should approximate the ideal mutton form as closely as possible. He should have quality along with size. He must not be coarse or rough. He should be hearty, with a strong constitution, a dense fleece, and the characteristics that belong to his breed.

AGE OF RAM

In flocks of ten to twelve ewes, bred as late as November or December, a lamb dropped in February or March may be used. However, the use of the ram lamb is not good practice. An older ram will serve a larger number of ewes in a shorter time. This means a lamb crop more uniform in age and size. In large flocks the yearling or two-year-old ram often serves three to four times as many ewes as the lamb should be permitted to serve.

NUMBER EWES PER RAM

Flocks up to forty or fifty ewes may be served by one ram if he receives the proper attention and care. Where the ram is turned with the ewes throughout the breeding season most breeders in West Virginia use a ran to each thirty to thirty-five ewes. Too large a number of ewes per ram will usually mean a smaller percentage of lambs.

BUYING RAMS

If satisfactory rams cannot be obtained locally, the flock owner may either order by mail from a reputable breeder or he may have his county agent place his order for a ram with the Extension Division of the College of Agriculture. For the past several years this service has been offered to the farmers and nearly a thousand purebred rams have been secured from within and without the state for flock owners. In any case, it is very unwise to use a grade or scrub ram.

THE BREEDING SEASON

Gestation Period

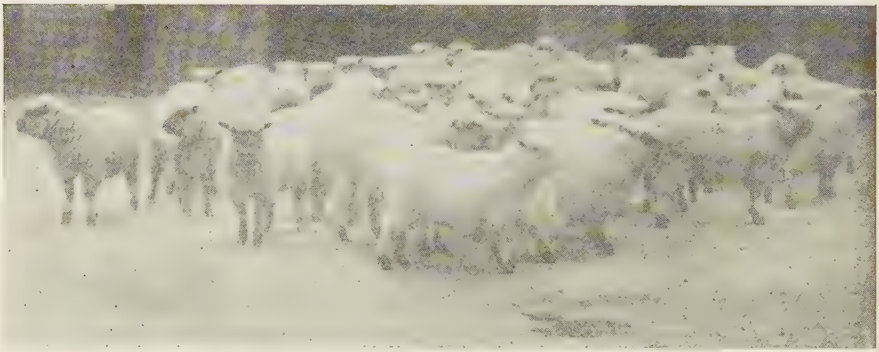
The exact number of days ewes carry their lambs varies slightly with individuals and breeds. As a general rule most ewes drop their lambs from 145 to 150 days after breeding. Ewes should be bred approximately five months before it is desired to have the first lambs.

Breeding Dates and Community Ram Day

As a means of promoting orderly marketing and a standardized lamb crop the West Virginia Livestock Shippers' Association began advocating Ram Day in various communities and counties of West Virginia. This movement started in the fall of 1926. Ram Day

means that most or all the sheep men of a community, district, or county, agree to turn the ram with the flock on a predetermined date.

The date agreed upon is determined largely by experienced sheepmen. Local conditions govern their selection and as a rule the date selected is perhaps the approximate ideal date in that community. The dates most commonly selected for 1926 were October 1, 15, and 31, and November 15 and 30. In so far as information is available at the present, it appears that a selection of one of the foregoing dates is advisable. The counties and communities in the southern part of the state prefer early October. The more northern counties late October and early November. Where sheep are to be grazed in the mountains and higher ranges of the Alleghenies breeding is deferred in a few instances until late November.



Grand Champion Carload of Lambs at International Livestock Exposition in 1926. Note the Uniformity of the Lambs Which Had an Average Weight of 85 Pounds Each.

There are several advantages in having the lambs of a section or community dropped simultaneously. Such practice permits the marketing of most of the lambs in a community at one shipment. Car loads of lambs are more easily gotten together. Lamb pooling and co-operative shipping are promoted.

Where concerted action is not in effect there is a tendency on the part of sheepmen to have lambs dropped over a period of six weeks or two months. Pooling and cooperative shipping are less likely to succeed and many shipments of small lots must be made or else some lambs are extra heavy while others are light for ideal market weight.

The adoption of a "Ram Day" upon which breeding is begun, as well as a day upon which the ram is to be removed from the flock is a most effective way to secure a large number of uniform standardized

lambs, and whether the lambs are sold to local buyers, are pooled and sold collectively, or are shipped cooperatively, the average price level is almost sure to be raised.

Treatment for Parasites

About two or three weeks before Ram Day the ewe flock should be treated for internal parasites. The method of treatment is given in another section of this circular (pages 41-44).

Tagging the Ewes

While the flock is penned for parasite treatment, the wool and tags from around the tail or dock of each ewe should be clipped off. This operation takes but a few minutes to perform but if it is not done, breeding may be hindered. Some ewes are barren because the wool and tags are so matted that service by the ram is impossible.

Flushing the Ewes

Many sheepmen arrange to give their flock especially good pasture two weeks prior to breeding. Such practice is known as "flushing." Shepherds have long believed that flushing ewes, by giving them better pasture or feeding a little grain just before breeding time increased the number of twins dropped. Experiments conducted by the United States Department of Agriculture over a period of six years bear out the shepherds' belief. Flushed ewes produced approximately 20 additional lambs per 100 ewes as compared with 100 ewes not flushed.

When ewes are flushed there is a tendency for most of them to come in heat promptly and the lambing season will be shortened. The lambs will be more nearly uniform in age and ready for market at more nearly the same time. Excessively fat ewes should not be flushed. It is a mistake to permit ewes to get over fat. Either starving ewes at breeding time or excessively fattening them is a bad practice.

The ideal plan is to have ewes in a medium condition of flesh, treated for parasites, tagged, flushed, and on better pasture or a little grain so that they are making gains when bred.

Preparing the Ram

The ram should be vigorous, and in good condition. If he is a little thin he should be given some oats and bran for two or three weeks before turning him with the ewes. A mixture of three parts oats and one part bran by weight is satisfactory. At the start the ram

should be fed about one-fourth of a pound of this mixture, increasing the amount fed daily until at the end of a week he is receiving one pound daily. The ram should be kept away from the ewes at all times other than during the breeding season.

Rams should not be kept in a lot near the ewes as under such conditions they rapidly lose flesh due to worrying or fighting. They may be run together, however, throughout the year until about the last of August or the first of September, but if they begin fighting at this time, it is well to separate them.

After the breeding season is over they may be turned together again. When they are first put together after the breeding season, they should be placed in a small pen or enclosure for a half day or so. They cannot fight much if they do not have room to back more than five feet. Occasionally good rams are seriously injured or even killed while fighting.

Methods of Mating

When more than one ram must be used and the rams are run with the flock it is better to divide the flock in two parts. In this way the rams cannot waste energy in fighting. As a rule several ewes will receive the ram the first time he is turned with them. This is nearly always true if they are gaining rapidly. In some experimental lots of ewes at this station as many as three to four ewes in lots of thirty have taken the ram the same afternoon he was turned with them. These ewes were bred within a few hours time. Under such conditions it is best to remove the ram and turn him with the ewes an hour in the early morning and again in the late afternoon. After two or three days he may be permitted to run with the ewes night and day.

When the breeder has suitable pens and equipment and will take the time necessary he may catch each ewe as soon as she is bred and turn her in a pasture away from the unbred ewes. If his flock is pure-bred he should record her ear tag number and the date bred. Three or four days after breeding she may be returned to the flock.

If the breeder of grade ewes cares to keep a record of the breeding dates he may do so by smearing the ram between the fore legs with a color mixture. Each ewe served by him will be marked. Lamp black mixed with a light engine oil and kerosene, half and half, will serve for one color, and Venetian red with the foregoing oil mixture for another. The first color should be applied every two or three days for sixteen days, and a change made to the second color on the seventeenth day.

This method makes it possible for the breeder to know the ewes

that have not settled from the first service. In case but one ram is used, and he fails to settle his ewes, the breeder is enabled to discover the fact before it is too late. A great many sheep men have lost part or all of a proposed lamb crop due to the ram failing to breed properly.

Ram Should be Removed

The ram should be taken away from the flock when the breeding season is over which will be after six to eight weeks. There is no good reason for leaving him longer. Any ewe that is not bred at the end of this period will have a lamb so late that but little profit will be returned for its rearing. Numbers of sheepmen have experienced losses by having the ram knock the ewes about.

During the winter season the ram should be fed some good hay and a little grain. Corn silage, if available will keep him in good shape. Many farmers let the ram run with the cows and have but little trouble caring for him aside from his feeding in winter.

THE BRED EWE

After the ewes are bred they should be handled so as to permit their making a gain of from five to ten pounds in weight. If the ewes are thin at breeding time they should gain even more than this. Ewes so handled will produce stronger lambs and a better fleece.

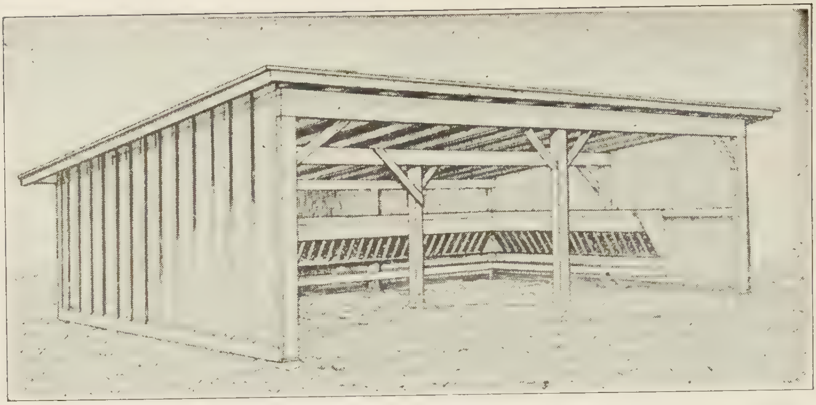
The Roughage Needed

As long as pasture is good it will suffice for roughage, but when heavy snows come and vegetation freezes it is necessary that a good legume hay be used. Some flock owners make the mistake of trying to feed thin ewes straw or timothy hay. These materials will not properly nourish bred ewes. Good clover, soybean, or alfalfa hay will largely meet all the requirements of the bred ewe until near lambing time when a little grain should be fed.

If the ewes are kept in a good, thrifty, vigorous condition, no grain will be necessary until from four to six weeks before lambing time. Silage, if available, should be fed along with the hay. Much less trouble from impaction and constipation will result and the ewes will be more alert, vigorous, and thrifty.

The Grain Ration

Oats and wheat bran made up of four parts oats and one part bran by weight make a good grain ration for bred ewes. One pound of this mixture to each five or six ewes should be fed at the start.



An Inexpensive But Comfortable Sheep Shed. Note the Combined Rack and Trough for Feeding. Gates That Open Outward May be Used on the Open Front if Desired.

After the ewes have all begun to eat, the amount allowed may be increased gradually up to three-fourths of a pound per ewe, or even one pound per ewe may be fed if the condition of the ewes make this amount essential.

Feeds of poor quality should not be used. Coarse, musty, hays of low feeding value, silage that is semi-spoiled or frozen, and musty grain should not be fed. Clean troughs should be used for feeding the grain and silage and the hay should be fed in racks.

Exercise for Bred Ewes

When the weather will permit the ewes to graze, no other method can equal this for keeping the ewes vigorous. When grazing is not available the access to bright corn fodder spread over the frozen ground or snow away from the barn will be found helpful. Many ewes are lost from lack of exercise and its attendant evil—constipation. A little linseed oil meal will be found useful in keeping the bowels in good condition, especially if it is necessary to feed a low-grade roughage.

Housing Bred Ewes

Many sheepmen in West Virginia are providing winter quarters for their flock and finding it profitable. The cold rains of late November and early December thoroughly soak the fleeces of sheep and they remain wet for days. As a result the flock begins coughing and running at the nose. Loss of flesh ensues and even death from pneumonia often occurs.

Any shelter provided for sheep should have certain features but

in no case is an elaborate or expensive building necessary. A shed-type structure open at the south or south-east with the ends and back closed will serve in most cases. If the shed has wide gates or doors, a good roof, dry floors, plenty of light and air, and ample room, the exact style of the building is of minor importance.

Narrow doors or gates will result in ewes that are heavy with lamb being hurt and some of them may abort due to the flock rushing through the narrow opening. Damp floors and leaky roofs are a menace to health and the flock will not thrive under such conditions. Sheep must have fresh air, but it is not necessary to have a draught. If the front of the shed is left open, there will be opportunity for light, air, and sun to do their good work.

Some owners over-crowd their flocks. A minimum of from 10 to 12 square feet of floor space per ewe should be allowed. On an average 18 inches of trough and rack room are necessary to avoid crowding. The feed racks should be arranged so that hay, chaff, and dirt will not contaminate the wool. It is very bad practice to throw hay into the rack over the backs of the flock. It is even worse practice to allow the flock to run to hay or straw stacks. The hay and chaff and seed work into the wool and it is then graded as burry and seedy, and

A Combined Hay Rack and Feed Trough for Sheep. Plans for Constructing Such a Rack May be Obtained Free Upon Request to the Animal Husbandry Department of the College of Agriculture.

this grade of wool brings from five to ten cents less per pound than if it were clean.

LAMBING TIME

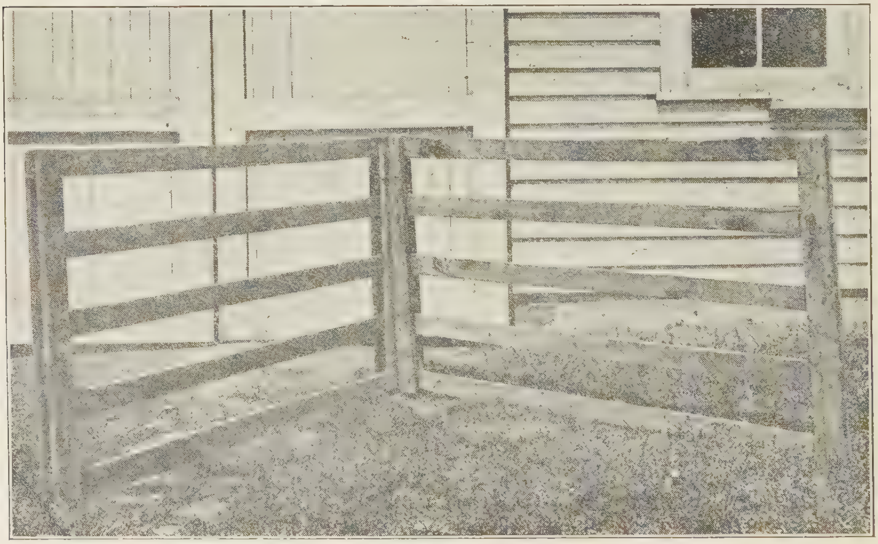
Individual Pens

It is very important that the sheepman be ready for the first lamb. Most ewes carry their lambs about 147 days. The barn or shed should be cleaned two weeks prior to the date the first lamb is due. Several small pens made up of panels about 30 inches high and 4 feet long should be on hand. With these pens the flock owner can keep the ewes and lambs under his care and control and avoid lambs being chilled and disowned.

As soon as the ewe has lambed she and her offspring may be penned for a day or so and then turned away from the ewes that have not yet lambed. The ewe recognizes her young by sight, and voice. She depends upon her sense of smell largely at first and if one of twins happens to stray off she will accept the one with her and disown the lamb that strayed away. The small pens prevent this.

Assisting Lambing Ewes

Occasionally a ewe is unable to give birth to her lamb. When such a case occurs the shepherd should give assistance. Before at-



Hurdles for Use in the Sheep Shed or Barn in Penning Each Ewe to Herself for a Day or Two When Her Lamb First Arrives Are Life-Savers. It Pays to Use Them.

tempting to help the ewe he should wash his hands in water containing sheep dip or creolin, trim his finger nails, and grease his hands with raw linseed oil, unsalted clean lard, or carbolated vaseline.

An examination will, in most cases, suggest the proper help. One of the first things is to make sure that the legs and head are in a normal position. Great care should be exercised in pulling on the lamb so as to be as gentle as possible. The passages should be smeared with pure raw linseed oil, carbolated vaseline, or pure clean unsalted lard.

It should be remembered that it is absolutely necessary to be clean and to disinfect the hands, both before and after assisting the ewe. Not only is it possible for the ewe to die of blood poisoning, if careless methods are used, but the attendant must protect himself as well. The most successful help can be rendered by a person with small hands and one who will exercise patience and care. Injury to the womb should be prevented; if at all possible.

Care of Newly Lambed Ewes

A newly lambed ewe should be observed carefully twice daily, morning and evening, to make sure that the lamb or lambs are taking all of the milk from her udder. In case the lamb does not take all the milk, the ewe should be milked dry by hand. Sometimes a lamb nurses but one side of the udder, and in other cases the ewe gives more than the lamb or lambs can take. As a result the ewe's udder will get hot and feverish and will cake and spoil if neglected.

CAKED UDDERS

When a ewe's udder becomes caked, she should be set on her rump and her udder bathed from five to ten minutes with water no warmer than the hand can readily bear. The udder should be dried with a clean cloth by rubbing gently, and pure melted lard, sweet oil, or olive oil applied. This treatment should be repeated at least three times daily until the condition is relieved.

AVOIDANCE OF UDDER TROUBLE

Udder trouble may usually be avoided by observing each ewe's udder carefully from time to time, and especially large-uddered heavy milking ewes. Upon the first signs of trouble the udder should be milked dry. The ewes should not be permitted to bed on damp floors or frozen ground. But little grain should be fed for three days after lambing, gradually coming back to the full allowance. Succulent feed, like silage, is desirable and should be fed, if possible. The ewes

should have an abundance of clean water available at all times. Sheep will suffer for water rather than wade mud, and may often be within 100 yards of water and not go for a drink.

SORE TEATS

Lambs have sharp teeth, and many times they bite the mother's teats and make them sore. A ewe with sore teats very naturally refuses to let her lamb nurse. In such cases the udder should be milked out and the sore teats smeared with carbolated vaseline. This should be done several times daily. The lambs teeth should be examined and if sharp points are found, they should be smoothed off with a file.

Care of Young Lambs

DISOWNED LAMBS

When a ewe disowns her lamb and has plenty of milk the attendant should tie her by the neck or with a small halter so she cannot butt the lamb, and hold her at two to three hour intervals for the first day or so for the lamb to nurse. Most ewes will stand quietly after being held for a few times, and let the lamb nurse when the attendant approaches the pen.

If the ewe is given proper feed and water and treated kindly, as a rule, in from two days to two weeks, she will own the lamb and cause no further trouble.

There are other ways of achieving the desired end, such as rubbing the ewe's milk or the foetal fluids when they may be obtained, on the lamb, or by bringing a dog near.

In case a ewe loses her lamb and it is desirable to give her another lamb, it may be accomplished by tying her in a small pen, removing the skin from the dead lamb, and fastening it on the lamb that is to be put with her. The extra skin should not be left on longer than a day or so, so it will begin to irritate the skin of the live lamb.

WEAK LAMBS

Even in flocks that have had most excellent care lambs are sometimes born weak and almost lifeless. The weak lamb needs assistance; it should be held up to its mother's udder, the teat put in its mouth; and some milk drawn with the fingers. This should be repeated until the lamb has gained sufficient strength to stand and nurse.

The shepherd will be repaid if he will see to it that each new born lamb gets a full feeding of milk as soon as it can stand and nurse. Locks of wool often cover the teats and the lamb attempts to nurse

the lock. Any locks that interfere should be removed. Sometimes wax clogs the teats making it necessary to squeeze the teat to remove the obstruction before the lamb can nurse.

Some lambs are exhausted at birth due to delay in being born and the difficulties of birth. Such lambs scarcely move. In a case of this kind of shepherd must act with all possible speed. He should wipe the mucus from the lamb's mouth and nostrils, and open its mouth, and blow in it gently four or five times to start the breathing process. He should then lay the lamb with its feet beneath the body and alternately lightly squeeze and relax the chest by applying the hands just back of the shoulders. By alternating the blowing and squeezing a lamb that is apparently dead may be revived.

CHILLED LAMBS

When a lamb becomes chilled on account of exposure or extreme cold at or shortly after being born, it will die unless it is given assistance. It should be placed in a tub or pan of warm water—no warmer than the hand can bear—and allowed to remain for a short while, care being exercised to prevent drowning. When it is removed from the water it should be rubbed dry with a large bath towel, and wrapped in a warm dry cloth to keep it warm.

When signs of strength appear it should still be kept wrapped but allowed to nurse its mother. When it is strong again it should be placed in a pen with its mother, and watched carefully for several days.

Chilled lambs are nearly always affected by constipation. Castor oil, one-half to one teaspoonful, should be given if signs of constipation become evident. If the first dose does not relieve the lamb additional doses should be given until the condition is corrected.

ORPHAN LAMBS

Sometimes it is necessary to raise lambs by hand. In such cases it is advisable to use a swan-billed nipple on an eight-ounce bottle for feeding. The orphan lamb should be fed whole milk from a fresh cow at intervals of two to three hours for the first two or three days, after which the time between feeds may be gradually lengthened until the lamb is receiving three feeds daily. At first not more than two ounces should be fed at one time. The amount may be gradually increased as the lamb grows and the time between feeding is lengthened.

Cow's milk is not as rich as ewes' milk and should not be diluted when fed to lambs as is often done with poor results. Another common mistake in bottle-feeding lambs is to give too much at one time

and making the time between feedings too long. Young lambs cannot stand gorging but require nourishment frequently.

Bottle-fed lambs are often troubled with constipation or scours. In such cases each lamb should be given a teaspoonful of castor oil as often as needed to keep the bowels in good condition. Scours are usually caused by over-feeding, irregular feeding, or by the use of dirty nipples or bottle.

Ailments of Young Lambs

PINNING

When the first fecal material passes from young lambs it is very sticky. Oftentimes this material adheres to the skin, wool, and tail of the lamb, hardening after being passed from the lamb and completely sealing the anus. If this occurs the lamb is unable to void waste matter, and as a result of self poisoning, sickens and dies. To relieve the lamb, the accumulation should be scraped away and the parts washed clean with warm water.

CONSTIPATION

Improper feeding of the mother or chilling of the lamb sometimes results in difficult passage of the fecal material. In such cases it is advisable to make up a milk-warm soapy solution and inject it into the rectum with a small syringe. In addition, the lamb should be given a teaspoonful of castor oil.

INDIGESTION

If a lamb begins to froth at the mouth and shows signs of great pain it is most likely suffering from an attack of acute indigestion. A tablespoonful of castor oil usually brings relief.

SORE EYES

When lambs are afflicted with sore eyes, tears flow freely, the lids are red and inflamed and the eye-ball appears milky or white.

The eyes should be examined and if the eye-lashes are turned inward, they should be carefully opened and fastened in the correct position by using a disinfected needle and white thread. The needle should be inserted in the skin of the eye lid as near the lashes as possible and again in the skin of the lid well back from the lashes, and the thread tied so that the lid remains open. The thread will slough out, but by the time it has done so the lid will have thickened and ceased to curl downward.

If the lashes are not turned inward, an eye wash, silver nitrate or argyrol, should be procured from a druggist, and the eyes bathed frequently until relief is effected.

In either case, care should be exercised to have the hands and all other agents that come in contact with the eyes scrupulously clean.

SORE MOUTH

When scabs form on the mouth and nose of the lambs they should be rubbed off and the treatment applied for lip and leg ulceration given in the section of this circular devoted to "Prevalent Ailments and Diseases of Sheep" (page 41). This trouble will spread from lamb to lamb if the attendant does not act promptly.

GROWING THE LAMBS

After the lambs are about a week old, the shepherd's chief attention may be devoted to making a marketable commodity of his lamb. Rapid unchecked growth until marketable weight and fatness are obtained is his chief concern. To achieve this end, the ewe should be fed a ration, or put on pasture, that will stimulate her milk flow to the utmost. If grain is fed, milk-making material such as bran and oats should be used, and after the first week a little corn and linseed oil meal may be added to the ration.

Sudden Changes

If a change of feeds seems desirable, it should be made gradually, changing a very little each day. Sudden changes may cause digestive disturbance in the ewe and she may transmit the disturbance to her lamb. Sudden gorges of green feed should be avoided by giving the ewe access to pasture for an hour or so at first and lengthening the period each day.

Variety of Feeds

It is better to give several different kinds of feed all the time than to change from one feed to another from day to day. If ewes are on a varied wholesome ration before lambing, they should be kept on approximately the same ration after lambing. There is no need to change a good ration.

Water and Salt Important

It is very important that the nursing ewe and growing lamb have daily access to salt and all the clean drinking water they wish. Unless salt is kept before the flock at all times there is danger that the ewes may eat too much at one time when it is supplied. An abundance of good water insures a good milk flow, provided pasture and other conditions are as they should be, and enables the ewes to suckle their

lambs well which is half the secret of success in raising a good crop of marketable lambs.

Ewes May Lose Flesh

There is no reason for being alarmed if a ewe declines in fatness or condition after lambing if her lamb is growing plump and is strong and playful. Such appearance indicates proper growth of the lamb due to the mother supplying abundance of milk. A fat ewe and thin lamb indicates a poor milking mother, and such ewes should be marked for slaughter.

Feeding Grain

Lambs ten days old will begin to nibble grain. Very early lambs, arriving before grass, and pure-bred lambs need grain for proper growth. It is desirable to bring purebred lambs to maturity quickly. Grain feeding will do this and will give them the finish and plumpness demanded by the buyer of breeding stock. When grass dries up in early July a little grain will help fatten the grade lambs and get them ready for market much more quickly than will grass alone.

A suitable grain mixture for lambs may be made by mixing by weight, two parts ground corn, two parts crushed or rolled oats, one part wheat bran, and one part linseed oil meal.

The mixture should be placed in a flat botton trough, and a hood or board placed eight inches above the trough, as wide as and parallel with the bottom, to keep the lambs from getting into the trough with their feet, and the feed from being mussed or soiled.

Amount of Feed

For the first two or three weeks lambs will merely nibble grain, but by the time they are a month old each lamb will be eating approximately a quarter of a pound of grain mixture daily. Whole grain may be substituted for the ground corn and crushed oats at this time and the lambs fed as much as they will consume.

Lamb Creeps

The feed trough should be placed in a pen that has openings large enough to permit the lambs to pass but small enough to exclude the ewes, and the openings enlarged as the lambs grow larger. When lambs are dropped in the pasture and it seems desirable to feed them

grain, a creep may be placed at a convenient place in the field, preferably where there is shade or shelter.

Docking and Castration

Docking is the name given by sheepmen to the operation of cutting off the tail. Castration is the name applied to removal of the testicles of male animals.

During the past two years the West Virginia Co-operative Livestock Shippers' Association, the State Department of Agriculture, and the Agricultural Extension Division and Animal Husbandry Department of West Virginia University have co-operated in holding docking and castration field demonstration in twenty counties of the state. A uniform practice has been demonstrated and recommended to farmers and sheep owners in these counties.

Briefly the reason for performing the operations are: Docking is performed due to the tendency of sheep to befoul long tails with feces. Such befoulment is unhealthy; flies are attracted and eggs are deposited by them. Often this results in maggots developing and burrowing under the skin of sheep and lambs. If the owner fails to discover this condition permanent injury and many times death results.

Docking Irons and a Good Knife for Castration. Note the Length of the Knife Blade, 3½ to 4 Inches.

The mating, lambing, and general health of the breeding ewe makes the operation of docking imperative. Few ewes are to be found with long tails, as more than 95 per cent of breeding ewes are docked. Lambs, both ewes and wethers, intended for market should be docked as this gives them a cleaner and more tidy appearance. As a rule, docked lambs of equal merit are more attractive to the buyer than undocked lambs.

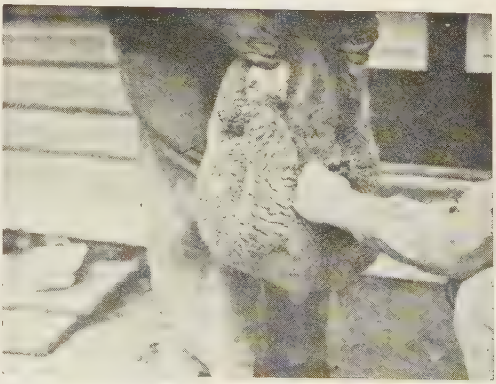
Castration of ram lambs is performed because of the fact that sexual development interferes with proper fattening for the block. When ram lambs are marketed at or before reaching the age of four months masculine development is not as marked and the effect of castration is perhaps not as noticeable. Ram lambs over four months, tend to grow in size rather than fatten. They develop heavy heads, more muscular necks, coarser shoulders and frames, and large sexual

The First Step in Castration. Cutting Off ⅓ of the Scrotum. Note How the Lamb is Being Held Which is the Proper Position for This Operation.

organs. They become restless. They not only spend less time eating and lying down but they annoy the ewe lambs. The total effect results in many of them being sold at a lower price than the ewes and wethers from the same load of lambs.

Ram lambs that are not fat due to sexual development and its attendant activity, that are four and one-half months old or over, and that arrive on a market over supplied with lambs or much after the middle of August may be penalized in price very markedly. The explanation for this lower price is simple. These lambs dress less meat for each 100 pounds live weight, and the meat is of inferior quality as compared with ewe and wether lambs.

The operations of docking and castration are necessary and in order to attain success, to avoid loss, and to perform the operation humanely the following methods have been used and advocated by the several agencies demonstrating in the field. If the flock owner lacks experience and desires a demonstration, he should call the county agent, or a neighbor may be able to give the desired assistance.



Forcing the Testicles Out and Holding the Cords by Clamping the Outer Walls of the Scrotum Close Up to the Body With the Thumb and Finger of the Left Hand. Note That Lamb is Not Held Properly.

WEATHER CONDITIONS

A bright crisp day should be selected for castrating lambs rather than a cold wet rainy day. The

Grasping the Testicle With the Thumb and Finger of the Right Hand and Pulling it Out Quickly. The Lamb is Being Held in a Poor Position to Better Show the Operation.

vitality of the lambs is not as great on a raw damp day as on a sunshiny day.

NEEDED REST

When lambs are to be docked and castrated they should be kept in confinement for a time where they will be quiet. The operations should not be performed immediately after driving the lambs a distance, when they are excited, or have been running. If the lambs are rested and remain quiet they bleed much less than when worried and hot. In catching them the attendant should be as quiet, careful, and gentle as possible.

CLEAN PLACE ESSENTIAL

The sheep and lambs should be penned in a clean place and the lambs put down in a clean place after the operation. Filthy pens, barns, and barn lots may cause the owner endless trouble due to infected wounds. A clean pasture is a splendid place for the lambs after operation.

PROPER AGE

Lambs one to two weeks old are of almost ideal age to withstand the shock of the operation. Lambs much younger lack sufficient vitality and older lambs suffer more from bleeding and shock. Many sheep men make the mistake of waiting until all the lambs arrive to perform these operations. If some condition is not right and trouble arises all the lambs are exposed.

The Final Step in Castration, Applying a Disinfectant to the Wound. Note That the Attendant is Not Holding the Lamb Properly Which Places it Under a Strain.

The correct procedure is to operate at least once a week on all lambs of proper age.

ANTISEPTIC IMPORTANT

It is necessary that cleanliness be exercised in docking and castrating lambs. A disinfectant such as cresol or lysol, should be used. This should be prepared in a clean basin using clean water. The operator should wash his hands and knife in the solution before beginning to operate. The knife should be kept in the solution when not in use and the hands dipped in it each time a lamb is operated upon.

SHARP KNIFE NEEDED

A sharp knife free from a "wire" edge with a blade three and one-half to four inches long permits the operator to sever the scrotum or the tail at one stroke. The edge should be kept in good condition by means of an oil stone.

METHOD OF OPERATING

Castration—The attendant should hold the ram lamb as shown in the illustration at the top of page 28. The person performing the operation should grasp the end of the scrotum and at one stroke cut off its lower one-third. With the thumb and finger of one hand he should hold the cords attached to the testicle by clamping the outer walls of the scrotum close up to the body, while he inserts the thumb and finger of his other hand inside the scrotum until the entire length of the testicle is passed, so that he can close his thumb and finger above it. He should then hold fast with the thumb and finger of each hand and quickly draw the testicle away. The second testicle should be removed in the same manner and as speedily as possible. The wound should be disinfected.

Docking—The ram lambs should be docked immediately after being castrated and before being put down. The tail should be held out straight, the skin slipped toward the body, and the tail severed about one to one and a half inches from the body with one swift stroke of the knife.

The hot docking iron is also used for this operation. Healing is a little slower and the wound sloughs more so that in warm weather flies must be more carefully kept away from the wound. A fly repellant may be made by mixing lard and pine tar half and half and applying it to the wound. If the iron used is heated to a cherry red no bleeding will occur unless the tail is instantly snapped off. It should

be cut quickly rather than by snapping the hot blades together. The foregoing directions apply also to the docking of ewe lambs.

OPERATE IN THE MORNING

If the flock owner will perform the operations of castrating and docking early in the morning he will have opportunity to observe the lambs throughout the day. In case excessive bleeding occurs from the tail, a cord should be tied around the tail tightly enough to stop the blood, and removed in from two to three hours.

THE WOOL CROP

Wool is an important product of the flock. As a rule 20 to 25 per cent of the sales from the mutton flock may be expected from wool. Where fine wool sheep are kept a much larger percentage of the sales is from wool. The exact percentage return will depend upon the price of wool, its cost of production, and the care and skill exercised in the production and sale of this product.

The important factors influencing the value of wool that may be controlled by the grower are length, strength, color, and fineness of fiber, and condition of the fleece. These factors together with the amount of wool and the demand for wool products largely determine the price the manufacturer pays for wool.

Length and Strength of Wool

The length of fiber may be controlled by the grower, by selecting breeding stock having wool fiber two and one-half inches long and longer. If all of the grower's fleeces have fiber of such length his wool will be classed as combing wool. In the past few years the market price of combing wool has been higher than that of the shorter clothing wool. Careful selection of the breeding stock will enable the grower to produce a longer staple and receive this price advantage.

Care of the flock also has a bearing on the length of staple. Sickness, due to exposure or disease may cause a weak place in the fiber so that it breaks easily when tested with the fingers. Such fleeces may have the requisite length but due to the weak places are graded as clothing wool. It will pay the owner, therefore, to carefully look after the health, shelter, and feed of his flock.

Color of Wool

As in the case of length, the color of wool can be controlled by selection. Black and gray wools do not sell for as much per pound as white wool. Ewes that do not have all white fleeces should be

weeded out and discarded. If ewe lambs are to be kept for the flock, the fleece of the ram to be used should be examined and in case he has any black fiber in his fleece he should not be used, if it is possible to secure another ram as good and with a pure white fleece.

Fineness or Diameter of Fiber

The fineness or diameter of the wool fiber not only varies on the different sheep in a flock but also varies on the individual ewes. The wool on the thigh is coarser and of larger diameter than the wool on the shoulder, side, or back of a sheep. The owner who desires to improve the fineness of his wool clip must use care in the selection of his breeding animals, discarding the sheep that have coarse open fleeces or fleeces that vary greatly in fineness.

As a rule fineness of fiber may be determined by the density and compactness of the fleece. Wool that permits water and dirt to penetrate deeply is usually coarse. Also wool that lacks waviness, or crimp as it is called, is coarser than very wavy or crimpy wool.

Condition of the Wool

To receive the best possible price for wool it must be in good condition. The presence of burrs, seeds, chaff, and dirt all lower the value of the fleece. Whenever it is possible the weeds with burrs in the pasture should be kept cut down. If only a few burrs are present in the fleece when the sheep is shorn, they should be removed.

When feeding hay it should never be passed over the backs of the sheep, and sheep should not be permitted to run to hay or straw stacks. Hay racks that do not permit the seeds and chaff to fall into the head and neck wool should always be used. A little care exercised while feeding in the barn or on pasture will pay well.

Diseases or parasites leave their mark on the fleece of every sheep they affect. Shorter fiber, lighter fleeces, and even shedding of wool is a result of the owner's neglect of the flock as regards their health. Dipping for lice and ticks and treating for internal parasites as described elsewhere in this circular will not only give a heavier fleece of greater selling value but will prolong the average life of the flock.

Feeding for Wool

The maximum growth of wool is dependent upon the sheep being properly fed. Wool contains lime, phosphorous, sulphur, potash, and protein; so do the leguminous hays, such as clover, soybean,

and alfalfa. The clover in a good blue grass sod helps furnish the necessary materials. If then, a good legume hay is fed in winter and pasture partly made up of clover is used in summer, a large part of the wool growing requirements are easily met.

Grain mixtures mentioned elsewhere in this circular and silage will insure an even growth of strong staple. Changes in a satisfactory ration should be avoided, but if it becomes necessary or desirable to make a change it should be done gradually. Regularity of feeding is also an important factor in successful feeding. The amount to feed depends upon the condition and age of the flock. Young sheep need more feed than mature ones. In general, the flock should be fed so that it is in a good thrifty condition at all times.

Shearing and Preparing the Fleece for Market

As a rule, sheep should be shorn between May 1 and 15 except in the higher altitudes of the state. To shear just as early as the weather permits, is a good practice to follow. In the higher regions of the state shearing is usually a little later than in the lowlands.

At one time sheep were washed before shearing. This practice has ceased as it does not pay. Sheep should not be shorn when the fleece is damp unless the wool is thoroughly dried before being tied.

A Better Job of Shearing May be Done With the Machine Than With the Hand Shears; There Will be Less Second Cuts, the Fleece Will be Smoother, and Present a More Attractive Appearance.

All sheep should be tagged and in case there are only a few burrs in a fleece they should be removed, before starting to shear. Shearing should always be done in a clean dry place and the shearing floor kept clean.

The sheep should be kept off pasture for a short while before beginning to shear so they will not be too full of feed and hence uncomfortable while being handled. The sheep will be easier to shear if they are comfortable.

While shearing, the

sheep should be handled so that the fleece will not be torn apart. The shearing machine will do better work than hand shears. Regardless of the shear used "second cutting" of the wool should be avoided by shearing close to the body at all times. "Second cut" wool is penalized several cents per pound.

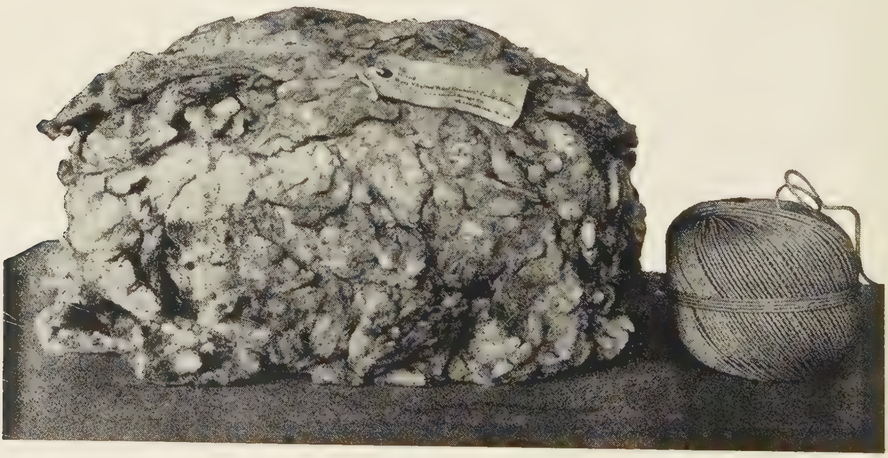
Care should be exercised to see that no straw, tags, or other foreign matter contaminates the shorn fleece. It should be folded lengthwise with the clean side out by folding from each side so that the loose ends are in the center. The ends should be folded to the center and the fleece then folded again. A good grade of paper wool twine should be used to tie the fleece, using no more than necessary. If a wool tying box is used, the fleece should not be tied too tightly, as this will cause it to appear too heavy for its bulk and it will be graded down. Two fleeces should never be tied together.

The tied fleeces should be placed in clean wool sacks, and all black, gry, dead, and tag wool bagged separately in clean feed sacks. The sacks should be sewed up or tied and stored in a clean dry place until marketed.

Cooperative Marketing

Many wool growers of the state market their wool through the West Virginia Wool Growers' Cooperative Association. In this way they learn the market grades they are producing and the grades that bring the highest price per pound.

The state association is now marketing wool through the same sales agency as the Ohio Wool Growers' Cooperative Association.



A Neatly Tied Fleece and a Ball of Paper Wool Twine. Sisal Binder Twine Should Never be Used for Tying Wool. Note the Square-Like Appearance of This Fleece.

The Wrong Way to Catch a Sheep. Grabbing by the Wool Tears the Skin Loose and is a Very Bad Practice.

This association has a successful record over a period of nine years in marketing wool.

Cooperative wool growers' associations have for their object the selling of wool on its merits, reducing the speculation in this product, working for a more stable market, standardizing, and advertising wool handled by them. They are in a degree securing for the grower compensation for superior methods of breeding, management, and preparation of wool.

CATCHING AND HANDLING SHEEP

Sheep are very easily injured by rough and careless handling. Undue excitement caused by hurried rough treatment while driving them is equally as bad. All rough treatment may easily be avoided by quietly driving the flock into a small lot or other enclosure and then by means of hurdles or gates, crowding and penning them tightly enough to prevent running. Once sheep are closely crowded catching is relatively easy. (See illustration on page 9.)

There are right and wrong ways of catching sheep. The wrong and cruel way is all too commonly practiced by ignorant flockmen. They almost invariably grab a sheep by its ears or wool. The skin of a sheep is very loosely attached to the body. Holding to the wool while the sheep

The Right Way to Catch a Sheep. Sheep May Also be Caught Without Injury by Placing the Hand Under the Jaw or by Grasping the Hind Leg Just Above the Hock.

The Wrong Way to Lead a Sheep Which Will Cause it to Struggle and Offer Resistance, Besides Hurting its Ears. There is Danger, Too, That a Ram May Knock the Attendant Over.

struggles often results in an area of skin being torn loose. When this happens weeks and even months may intervene before the sheep recovers from such an injury.

The right way to catch sheep are: under the jaws, by the hind flank, and above the hock. When sheep are first caught they often struggle unless closely pressed by other sheep or properly held. One of the best ways to quiet a struggling sheep and have it stand quietly is for the catcher to hold its head close to his body and cover its eyes. The accompanying illustrations show the proper method of catching, holding, and leading sheep.

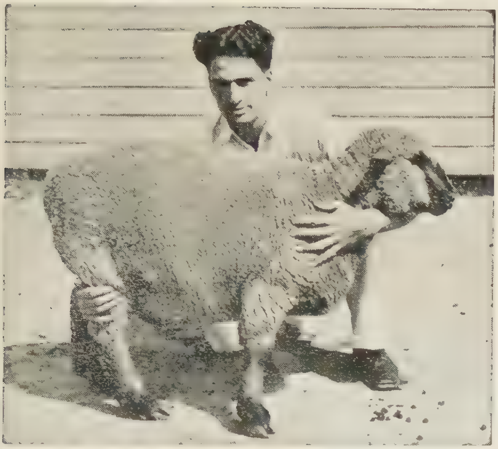
Trimming the Feet of Sheep

The hoofs of sheep grow very rapidly and if not watched may become so long and crooked that lameness results. This trouble may be remedied by trimming the feet with a good knife. The hoofs should be trimmed as often as is necessary to keep them short and level.

HOW TO TRIM

The sheep should be caught as instructed. The shepherd should stand on the left side of the sheep, place his left arm under its neck, and reach under the sheep with his right hand and grasp the right hind leg just above the hock. He should then lift up with his left arm and pull toward him with his right hand. The sheep will sit

The Right Way to Lead a Sheep. The Animal is Easily Held in This Way and May be Guided With the Hand Under Its Jaw While a Little Pressure on Its Rump Will Cause It to Move Forward.



The Right Way to Set a Sheep on Its Rump. The Man's Right Arm is in Front of the Sheep's Left Hind Leg. Pulling With His Right Hand and Lifting Up With His Left Arm Will Cause the Sheep to Sit Down.

down. He should step behind the sheep and pull it backward against his knees. A little practice will enable the average person to set the sheep down and hold it with very little exertion or struggle.

With the sheep in proper position all the feet may be reached and trimmed. All surplus hoof should be cut away and the toes when excessively long shortened. A little care must be exercised in cutting so as not to cause bleeding. By watching the toe the operator will observe as he cuts it short, a pinkish area near its end. When pink horn shows, bleeding will result if further paring is attempted.

Trimming a Sheep's Feet is Easily Accomplished, if the Animal is Held Properly as Shown in This Picture. This Position May be Attained Setting the Sheep on Its Rump and Then Stepping Behind It.

CULLING THE EWE FLOCK

Before the lambs have been separated from their mothers is the best time for the sheep man to cull his ewe flock and discard ewes that have dropped inferior lambs, those that are evidently poor mothers, or that are barren.

To cull the flock properly, the ewes that have poor, weak, or

ill-formed lambs should be marked, and after the lambs have gone to market, the cull ewes put on good pasture, fattened, and sold for slaughter. The flock owner in some cases will note that his best lambs are from ewes that are a little thin and not so attractive as certain other ewes. In such cases, if upon examination, the ewe proves sound and healthy, she should be kept. Heavy milking ewes often get thin while suckling their lambs.

Barren ewes will appear to be the best ones in the flock, but unless they are very young every one should be sold to the butcher. They have given only their fleece for their keep.

All diseased ewes should be discarded. As a rule it is not advisable to retain a broken mouthed ewe. She will have difficulty in feeding herself and lamb.

Many lambs are lost yearly because of the mother having a spoiled udder. If the udder of a ewe is not normal she is likely to milk poorly, if at all. The wise plan is to inspect the udder of each ewe and discard the ewes with bad ones.

The fleeces of the various ewes in the flock should be carefully noted at shearing time and any that shear light, short, coarse, or open, fuzzy fleeces should be marked and discarded at culling time.

If the owner will let the appearance of a ewe's lamb be his guide to her ability to produce and feed a good lamb; if he will dispose of barren ewes and replace them with ewes that will produce lambs; if he will examine his flock and discard unhealthy diseased ewes, old broken mouthed ewes, and those with poor fleeces or bad udders, his profits from next year's sales will more than repay him for his trouble, and his difficulties at lambing time next year will almost disappear.

GROWING AND MARKETING LAMBS

Practically all of the lambs in West Virginia dropped during the spring months are sold as fat market lambs during the summer and fall. As a rule the lambs run on pasture with their mothers until they reach weights of from 70 to 85 pounds.

Movement to market starts as early as June for a very few extremely early lambs, but marketing does not become general until July and August. Marketing continues until as late as November.

The late lambs as a rule come from the higher altitudes of the state. In the bluegrass area of the state, given pasture, water, salt, and shade, the ewe and growing lamb need little else for rapid growth from the time pasture appears until market time.

If very early marketing is desired, a creep should be placed in the pasture and the lambs fed grain. Shelled corn, 2 parts; whole oats, 2 parts; and wheat bran, 1 part, by weight, will serve to promote rapid growth. The lambs may be permitted to consume from one-half to one pound of this mixture daily.

If lambs intended for breeding stock are being fed, the corn should be omitted and 10 parts whole oats, 2 parts bran, and one part oil meal fed. In either case the trough should be kept clean. If possible the creep should be located reasonably close to shade and water. If the flock is regularly salted along side the creep but little difficulty

Shade is Essential to the Best Health of the Sheep Flock and the Proper Growth and Development of the Lambs. Where Natural Shade is Not Available, it Pays to Provide Shade by Artificial Means.

will be experienced in getting all the lambs to the feed. In the blue grass area, if lambs are not to be marketed by the middle of August they should be given a treatment for parasites as early as the first of July.

Selling Fat Lambs

There are three general methods in use by farmers at the present time for the disposal of their fat lambs. One method is the sale to local buyers at a contract price. Many lambs are thus disposed of long

before they are ready for the market. Up to within the last few years this practice was almost state wide.

The second general method is the pooling of lambs within a community. Under this plan the sheepmen of a community are usually enabled to secure a higher price from the local buyers due to superior bargaining power. The lambs pooled may or may not be of superior quality but an advantage to the growers is secured by concerted demands on the part of a large number of growers. Under the pool plan all farmers within the pool receive the same price irrespective of quality and grade, since this is not sound business, pooling does not stand in competition with cooperative marketing where lambs are sold on their merits.

The third general method is to market cooperatively. Under this plan the farmers arrange through a county manager to ship a full car load directly to the market. The lambs of each farmer are weighed, marked, loaded, and shipped to market and sold by a commission firm, either controlled by the producer or privately owned.

If an entire car load is sold at a specific price, each man shipping lambs in the car is charged his proportionate share of market cost and each receives the same net price per pound. Should any lambs in a car sell for a less price because of being inferior to the general run of lambs, these inferior lambs are weighed up and the grower is paid in accordance with what they bring. In any case the grower's lambs are sold as nearly as possible on their merits.

Marketing lambs through organized county livestock shippers' associations has become quite popular within the past several years. To the farmer who is producing standardized high grade lambs it offers one of the fairest means of obtaining the full market price for his stock. Without such associations the farmer who is a good sheepman and who puts in practice all of the methods necessary to secure a product of highest quality is often compelled to take the same price his neighbor receives for inferior lambs.

The local lamb buyer is practically compelled to pay a flat price for all the lambs he buys. The flock owner who neglects his sheep and lambs almost invariably demands as much for his lambs as the owner of choice well prepared lambs receives. In the districts and counties where strong shipping associations are operating the producer of inferior lambs has to sell his lambs on their merits. A few shipments will soon disclose to a community the type, weight, quality, and condition that brings the most money. In short, cooperative ship-

ping and selling of lambs is the most effective means of acquainting the producer with the market demands.

Keeping Ewe Lambs

A few sheep men do not market all of their lambs. They keep the ewe lambs and market the castrated rams or wethers. Where all the lambs are sent to market weaning takes place when the lambs are weighed for shipment. The flock owner should watch the udders of his ewes when the lambs are taken away. Some of the ewes may need milking.

In case ewe lambs are to be kept, they should be separated from their mothers at from four to five months of age, treated for parasites, and handled as a separate flock. These young and growing ewes can not be run with the old ewes to good advantage. They require better pasture and superior wintering. If ewe lambs are furnished good pasture and are well wintered by liberal feeding and are again given good pasture the following summer they will make valuable additions to the flock at breeding time as yearlings. In return for good care the first year, the owner will have a valuable fleece.

RATIONS FOR EWE LAMBS

Ewe lambs weighing 70 to 90 pounds may be wintered on from one and a half to two pounds of alfalfa, clover, or soybean hay, one to two pounds of corn silage, and from one-fourth to one pound of whole oats daily.

PREVALENT AILMENTS AND DISEASES OF SHEEP*

Sheep, like all other classes of livestock, are susceptible to many diseases and ailments. Parasites probably cause a greater financial loss to sheep owners, however, than all other diseases combined. Only a few of the most common and important diseases are discussed in this circular.

Parasites

STOMACH WORMS

Stomach worms are a type of parasites that live in the fourth or true stomach of sheep and cattle. The body of the worm is thread-like, may be red or white in color, and often has the appearance of being twisted. The average length is about one inch. The eggs are laid in the stomach of the sheep by the adult female parasite and

*This section of this circular was prepared by Dr. J. H. Rietz.

pass to the outside world with the feces. In a few hours to a few days, depending upon the temperature and amount of moisture present, a very small worm emerges from the egg. In a few more days this tiny worm crawls onto the grass blades or into the water supply and awaits being swallowed by some sheep with its food or water. If this tiny worm is taken into the stomach of a sheep in this stage of development, it grows into another stomach worm. The average life cycle, from the egg to the next generation of eggs, is about three weeks, under summer conditions. Considering that each adult female parasite lays hundreds and possibly thousands of eggs, it can be readily understood why the stomachs of sheep often contain hundreds of these parasites.

Sheep that are affected with stomach worms usually show unthriftiness, loss of flesh, dullness, paleness of skin, mucus membrane of the mouth, and covering of the eye balls. The appetite becomes poor, there is thirst, diarrhea, and often a dough like swelling of the throat, dewlap and brisket.

Drenching With a Dose Syringe. Note That the Nose is But Slightly Elevated. Raising the Nose Too High May Cause Strangling and Pneumonia May Result.

A certain diagnosis of any type of intestinal parasite may be obtained by forwarding a specimen of feces (dung) from the suspected animal, to the Veterinary Laboratory, West Virginia University, Morgantown, West Virginia.

Many drugs and combinations of drugs have been used to remove stomach worms, with varying degrees of success. Experience has shown that we have in Copper Sulphate (bluestone) a simple, effective

and comparaticely safe drug for the removal of these parasites. One condition must be kept in mind for the success of this remedy. Leave nothing to guesswork. All mixtures and dosages must be carefully measured and the details of preparation and treatment carried out.

The Dosage Syringe is a Great Help in Drenching. It is Advisable to Use a Graduated Measuring Glass to Insure the Correct and Accurate Dosage.

Sheep that are to be treated should be deprived of food for 18 to 24 hours before treatment. A constant supply of water should be provided. The sheep should be confined in a small enclosure, where they can be caught without undue excitement, running, and worrying. If there is no small enclosure, one should be built. Practically every farmer in West Virginia has waste posts and boards available from which suitable pens can be built.

In drenching a long-neck bottle should be used or better still a dose syringe which can be obtained through the County Farm Bureau or Extension Service. In drenching sheep, the nose should not be elevated too high. It should be raised only enough to be on a level with the eye. Raising the nose too high causes difficulty in swallowing and if strangling results some of the drench liquid may enter the wind-pipe and pneumonia may follow.

A one and one-half per cent ($1\frac{1}{2}\%$) solution of Copper Sulphate is used as the drench solution. This is made by dissolving one ounce of Copper Sulphate in exactly one-half gallon of water. This

quantity will be sufficient to treat approximately 20 adult sheep. This solution should be given in the following size doses:

Adult sheep	3	ounces
Yearlings	2	ounces
Six month old	1⅓	ounces
Three month old	⅔	ounce

A graduated measuring glass should be used to measure the exact dosage. Food and water should be withheld from the treated animals for three hours after treatment.

To successfully control stomach worm infestation on infected premises, it is necessary to treat the sheep regularly every three weeks, during the warmer months (April 1 to September 30). During the colder winter months, if the sheep are not allowed the run of a pasture where infected sheep have grazed during the previous twelve months, treatment will not be necessary.

NODULAR WORMS

The larvae or undeveloped stage of an intestinal worm causes the nodules or tumor-like formations along the intestines of sheep. These larvae live and develop in the nodules for six to seven months, when they pass into the bowel and become mature in another four months. At this time they deposit their eggs, which pass to the outside world with the feces.

If the moisture and temperature conditions are right, the young soon hatch and are taken up with the food and water by other sheep. After entering the bowel the young embryo burrows into the intestinal wall and again causes the formation of another nodule.

These parasites are not as long as the stomach worm, measuring less than three-fourths of an inch in length. They are white in color and are found in the intestines in greatest numbers from March until September. The adult parasites live in the large and small intestines of sheep and goats. The symptoms caused by nodular worms are not different from those caused by stomach worms and the same treatment is effective in the control.

TAPE WORMS

The white ribbon-like, segmented worms found in the intestines of sheep are tape worms. There are three species of tape worms found in the intestines of sheep. The largest of these specis may attain a length of 30 feet. Another species may grow to eight feet in

length. The smallest species measures only about six inches in length.

Tape worm infestation seems to be on the increase, consequently greater care should be exercised in watching the feces of the sheep for the white segments which are constantly being passed. These ripe segments, which are found in the feces of the sheep are packed full of the eggs of the tapeworm. These eggs undergo a number of changes and if finally they gain entrance to the digestive tract of a sheep, develop into another tapeworm.

The symptoms of tape worm infestation also are not different from those due to stomach worm infestation, and the same treatment that removes stomach worms will also remove the tape worms.

Sheep not only harbor tape worms in their intestines, but also fill the capacity of intermediate host to at least three intestinal tape worms of dogs. These intermediate forms of tape worms are the cysts or bladders containing the heads and necks of tapeworms. They are found in the abdominal cavity, connective tissue, brain cavities, and other similar parts of sheep. When the brain is the location of the cysts or bladders, the disease is known as "Gid." In this disease the sheep become nervous, travel in circles, often become blind and through inability to feed, loss of flesh, weakness, and death usually follows. If these bladders are eaten by dogs they develop into more tapeworms.

Treatment is not practical but each sheep owner should use his influence to control stray dogs. It is important for every farmer to see to it that his own farm dog and those of his neighbors are free from tapeworms.

LUNG WORMS

Three species of worms are known to inhabit the lungs of sheep. These worms are thread or hair-like, white, red, or brown in color and vary from one to three inches in length. The eggs are deposited in the bronchi (air tubes) of the lung by the adult parasite. The eggs or the newly hatched larvæ may be found in the discharge from the nose or saliva of infected animals. If the eggs or newly hatched worms fall into water or a moist place, they continue to develop and change, and if taken into the stomach of sheep, with the food, they find their way to the lung where they develop into mature worms.

The most noticeable symptom caused by these parasites is a dry cough, which becomes aggravated with exercise. There is usually a

mucus discharge from the nose and mouth. If the number of parasites is great, there is usually marked difficulty in breathing, paleness, and swelling of throat, dewlap, brisket, and eyelids. Weakness and even death may result.

The treatment for lung worms is not as satisfactory as the treatment for parasites of the digestive tract because the dangers from administration of the treatment are greater.

Chloroform administered slowly until the sheep is nearly anæsthetized has been recommended. This is accomplished by dropping chloroform slowly drop by drop into first one nostril and then the other.

The injection of 2 cc of a mixture of equal parts of olive oil and turpentine directly into the trachea (wind pipe) has some merit. The injection is made with a hypodermic syringe and care should be exercised to insert the needle between the rings of cartilage, to avoid injury to the trachea.

GRUB IN THE HEAD

Grub in the head is produced by the depositing of the living young of a fly on the nose of the sheep. The young larvæ travel up the nostrils and come to rest in the cavities of the head, where they cause irritation and very often very severe catarrh. The grubs remain in the cavities of the head for a period of ten months, before they descend to the outside world. Upon reaching the earth, the grub undergoes further changes, finally developing into another fly.

In heavy infestation the mucus discharge contains a large amount of pus. The air passages become filled and breathing may become very difficult. This causes dullness, sluggishness, loss of flesh, and weakness, and may lead to death.

Treatment is not satisfactory, but all efforts should be concentrated upon the prevention of the deposit of the larvæ by the fly. This is accomplished by using fly repellants on and about the nostrils of the sheep. Pine tar is highly recommended for this purpose. A very satisfactory method of application is the use of salt logs in the pasture. A number of two-inch auger holes are bored into a log. Salt is kept in these auger holes so that the noses of the sheep will become smeared when they attempt to eat the salt.

Providing a dark place for the sheep to lie during the day while the flies are most troublesome is also beneficial in reducing the amount of infestation.

LICE

Two species of lice infest sheep. These parasites are quite small, measuring only about 1-25 of one inch in length. The color is nearly white, and consequently it is difficult to detect their presence unless a very careful examination is made. Considerable damage is done by these parasites. There is loss of flesh, caused from worry due to the irritation of the skin and from the loss of wool as a result of the rubbing, pulling, and biting of the sheep.

Dipping is the only satisfactory method of control for these parasites. Specifications for a dipping vat may be obtained by writing to the Animal Husbandry Department, College of Agriculture, Morgantown, West Virginia. The dip solution should be of sufficient depth in the vat so the sheep can be completely submerged and the wool thoroughly soaked to the skin. This will require an average of one minute. Proper water tight drain pens should be provided or the loss of dip will be too great. A number of dip preparations have been used, with varying degrees of success. A few of the more common are coal-tar, creosote, creolin, cresol, nicotine, lime and sulphur, etc.

A five one-hundredth of one per cent (.05%) solution of nicotine sulphate is probably as effective in an all around way as any of the preparations. The directions for the proper dilutions are always given on the label on the cans and these directions should be followed. Two dippings, eight to ten days apart, are necessary to eradicate lice.

TICKS

The so-called "sheep tick" also known in certain sections of the country as the "large sheep louse" is neither a tick nor a louse but a species of wingless fly. This parasite is reddish brown in color and measures about one-fiftieth of an inch in length. The head is short and the body sack-like and leathery. The losses caused by this so-called tick are very similar to those caused by lice. Dipping is the only satisfactory method of controlling this parasite. The same general instructions regarding dipping as for lice is applicable for ticks.

Nicotine sulphate, when used in a seven one-hundredth of one per cent (.07%) solution, has proven satisfactory in the control of this parasite. Two dippings 24 to 28 days apart are necessary to eradicate sheep ticks.

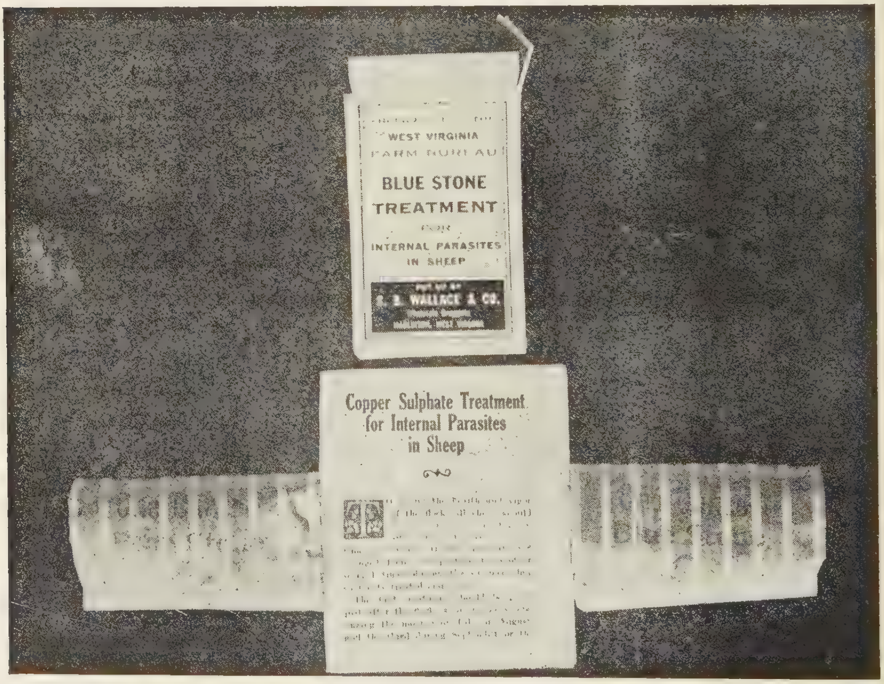
GENERAL REMARKS ON TREATMENT FOR PARASITES

The treatment described in this discussion for the various species

of parasites are not the only treatments that are effective, but these have been tried, are simple, and have given results. Various books, circulars, and bulletins on sheep contain much material recommending nostrums, powders, salts, etc., that are to be administered by feeding. This looks like an easy method of administration, but if a little labor is put into the effort to control parasites as has been suggested in the foregoing discussion, the results will well repay for the extra work required.

The West Virginia Farm Bureau has arranged with a wholesale drug firm to put up a carton of Copper Sulphate (bluestone) containing two one-ounce packages, as illustrated on this page. There are accurate directions in the package for mixing and the proper dosage for sheep. These packages may be secured through the local county farm bureau, local druggist, or through the Animal Husbandry Extension Service of the College of Agriculture.

In the treatment for stomach worms, some sheep owners have used a nicotine sulphate solution with good results. This preparation



Special Package of Copper Sulphate for Treating Sheep for Internal Parasites Put Up Specially for the West Virginia Farm Bureau. Each Carton Contains Two One-Ounce Packages and Full Directions for Using.

has proved effective in the removal of stomach worms, but it has the disadvantage of being poisonous in the concentrated form.

The nicotine sulphate (blackleaf 40) solution used for drenching is made by adding exactly one ounce of the Blackleaf 40 to one-half gallon of water.

A nicotine solution prepared as here described and added to an equal amount of copper sulphate solution (1½%) prepared as previously described may be used as a drench solution for stomach worms.

The dosage for either the nicotine sulphate or nicotine sulphate and copper sulphate mixture is the same as previously given for copper sulphate.

General Ailments

LIP AND LEG ULCERATIONS

Under the heading of lip and leg ulcerations may be grouped a number of diseases such as foot rot, necrotic dermatites (ulcerated skin) and necrotic stomatitis (ulcerated mouths), all of which are due to the same causative organisms. At least four forms of this disease may be recognized:

Foot-rot Form. In the form of this disease, commonly known as foot-rot, the ulcers are located between the toes and around the coronet, sometimes involving the structures under the horny layer of the hoof.

Sore-mouth Form. In the case of the sore-mouth form the ulcers are confined to the mouth, involving the lips, tongue or cheek. This type is quite frequent in young lambs.

Venereal Form. In the venereal form of the disease the ulcers located on the external genitals.

Lip and Leg Form. In the lip and leg form, the ulcers are located on the legs and mouth.

Frequently a combination of all forms are seen in one sheep. The foot-rot form is usually associated with wet seasons and muddy and often filthy yards. The water softens the tissues so that the specific germs gain an entrance to the tissues. In the remaining three forms the infection usually takes place through small scratches and cuts on the skin and mucus membrane.

The results from treatment of this disease by application of local antiseptics is very satisfactory if begun in time and applied energetically. In the lip and leg, mouth, and venereal forms, the local applica-

tion three times a week, of an ointment made by thoroughly mixing 5 parts creolin, 10 parts sublimed sulphur, and 100 parts vaseline or lard, has rendered satisfactory results.

In the foot-rot form, walking the sheep daily through a trough filled to the depth of six inches, with a 5 per cent bluestone solution has been found beneficial. Dipping the sheep in any of the recognized sheep dips is recommended for all forms of the disease after the local treatment has been carried out.

INDIGESTION

Several types of indigestion may occur in sheep. Two types only, impaction and bloating, need be discussed in this circular.

Impaction. Impaction of the rumen (paunch) is usually the result of dietetic errors. It may be caused by feeding moldy and fermented food, frozen or frosted grass, over-ripe hay, coarse woody food, as wheat and rye straw, tree tops, etc., or by a lack of sufficient water to supply the necessary moisture for digestion and the body in general. Overtaxing the digestive capacity of certain individuals by feeding too much good food may also result in impaction. This occurs usually in the fattening yards, or in cases where the animals have gained access to grain bins.

The symptoms of impaction are: The animal loses its appetite, stands apart from the flock, does not chew its cud, and has its feet drawn up under its body. The body appears a little more rounded than usual, with slight swelling of the left flank, which has a doughy feeling on pressure. There may be colicky pains which are indicated by restlessnss. Usually the animal is constipated, but occasionally there may be diarrhea.

In treating impaction all food should be withheld for a day or two, and fresh water in liberal quantities provided. Salt should be given in the water to induce drinking. The abdomen over the left side and flank should be kneaded for fifteen minutes, four times, three hours apart. The animal should be given a mixture made of three tablespoonfuls of salt, one teaspoonful of ginger and enough molasses to make a paste. This may be given by smearing it on the back of the tongue.

Bloating. In this form of indigestion, there is usually a rapid distention of the abdomen due to gas formed from the fermentation of the contents of the rumen (paunch). This condition often occurs in the spring of the year when sheep are first turned to pasture, and

in late summer when the sheep are changed from mature pastures to young immature second growth clover and alfalfa.

Young, immature grass, clover, and alfalfa, especially when wet by rain or dew, is liable to cause bloating. Food which readily ferments, as potatoes, beets, and wilted or heated grass, are liable to cause bloating. Certain wild plants, as larkspur and certain lupines, may at times be responsible for this condition. Foreign bodies (choke) lodged in the esophagus may cause acute bloating.

The symptoms are great distention of the abdomen, especially the left flank, restlessness, anxious expression, difficult breathing, etc.

Treatment consists of kneading the abdomen as in impaction, elevating the front feet, and forcing the sheep to walk up a steep hill. Medicine plays only a very subordinate part in the treatment of bloating. One-half ounce of oil of turpentine in two ounces of raw linseed oil may be of some benefit in promoting belching. When the life of the sheep is threatened, more radical measures are justified in inserting a trocar into the rumen through the highest point of the swelling of the left flank and allowing the gas to escape.

After the gas has escaped, a small dose of salts (2 to 4 oz.) or castor oil (2 to 4 oz.) should be given and the rumen kneaded long and well.

Bloating can largely be prevented by using care in pasturing early in the spring or changing to second growth meadows in the fall. The sheep should be turned on the grass only for a short time each day until they have become adjusted to the new diet. They should not be turned out in the morning until after the dew is off, and turning to pasture after a shower should be avoided.

Change of feed from poor pasture or dry feed to an abundant pasture should be made with caution.

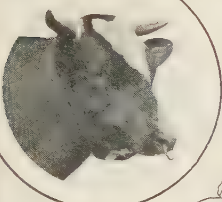
CIRCULAR 49

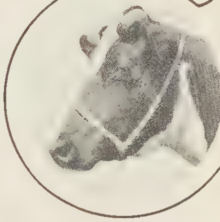
JANUARY 1928

BUILDINGS AND EQUIPMENT FOR THE DAIRY FARM

BY

F. D CORNELL, JR.





AGRICULTURAL
EXPERIMENT STATION
COLLEGE OF AGRICULTURE

WEST VIRGINIA
UNIVERSITY
MORGANTOWN

A modern, well-planned dairy barn adds to the value and attractiveness of the dairy farm.

Buildings and Equipment for the Dairy Farm

The dairy industry in West Virginia has been growing very rapidly in importance as a farm enterprise in the past few years. Farmers more and more are feeling the need for information and help in solving the problems incident to the housing and handling of the dairy herd, and the sanitary production of dairy products. Adequate housing facilities for the milking herd have a very important bearing on the production as well as on the health of the animals.

In order that they may be an economically profitable investment, however, there are certain points which must be kept in mind in planning the dairy buildings. It is lack of consideration of these essentials in barn planning that has been largely responsible for the rather serious mistakes that have been made in the erection of many of the present structures. Oftentimes mistakes are recognized as such only after it is too late. In the case of any building, mistakes are very difficult to correct after the structure is finished. The time to eliminate errors in construction and arrangement is when the building is on paper.

ESSENTIALS IN SUCCESSFUL BARN PLANNING

The essential points which should be kept in mind in evolving a desirable and successful barn plan are convenience, sanitation, durability and economy, warmth and ventilation, proper storage space, and appearance.

Convenience

The value of convenience in the interior arrangement of a barn is readily recognized. The various factors in the plan should be so arranged that the milking, cleaning, and feeding may be accomplished with a minimum expenditure of time and energy. Many hours of

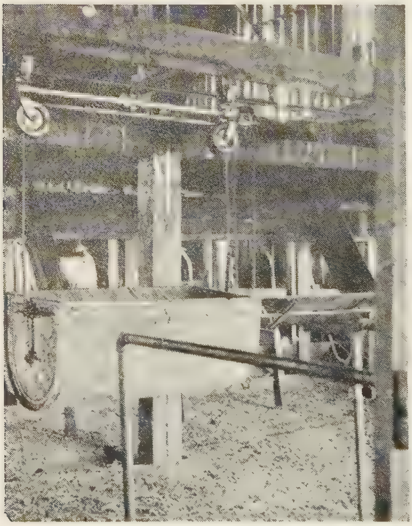
---

Acknowledgment is here made of the helpful suggestions received from Professor E. L. Anthony, head of the Dairy Husbandry Department, College of Agriculture, West Virginia University, in the preparation of this circular.

work in the barn are necessary, and with prevailing high prices for labor, even slight mistakes in interior arrangement may prove very costly over a period of time. In probably no other building on the farm do mistakes in planning make the tasks more irksome or cause greater hardships than in the dairy barn. The best way to arrive at a solution for this problem is to study the proposed plan very carefully, compare it with plans which have been worked out in detail and actually tried, then make the necessary changes on paper before submitting the final plan to the carpenter or contractor.

Sanitation

In the planning of a dairy barn the sanitary features of construction deserve special attention. This is not only important from the standpoint of health and comfort of the animals, but since the products of the dairy are used for human food they should be produced under as sanitary conditions as possible. Adequate light, floors and walls that are easily kept clean, and a minimum of corners or ledges where dust and dirt may accumulate are all features of sanitation. Sanitation is also the best insurance against the spread of transmissible diseases. Provision for the proper handling and disposal of manure is also included in this feature.



The old type of stable construction has many unnecessary obstructions that make proper sanitation difficult.

Durability and Economy

The features of durability and economy are closely linked together. Durability and minimum upkeep at as low an initial cost as possible are wanted in any farm building. A somewhat higher initial cost in construction should mean low upkeep, a longer period of usefulness, and in the long run be considerably cheaper than "the cheapest at any cost" type of construction. Since farm buildings are erected for a period of years it is advisable to consider the feature of economy from this viewpoint rather than from the viewpoint of initial cost only.

Warmth and Ventilation

Warmth and ventilation have to do with the comfort and health of the animals in the barn, and are important from the standpoint of production as well. A system of ventilation is essential to supply the animals with the necessary fresh air and to aid in keeping the barn warm, dry, and free from foul odors. Condensed moisture on the walls and ceiling gives evidence of the need for ventilation. In a properly constructed and well ventilated barn the heat given off by the animals from their bodies is sufficient to keep the barn at a comfortable temperature during the winter.

A modern dairy barn designed to house a large herd.

Proper Storage Space

A common and often very serious mistake in the planning of buildings is the failure to provide adequate storage facilities for the necessary feed and supplies. The average cow consumes about one and one half tons of hay yearly. To store a ton of loose hay requires a storage space of 500 cubic feet. A ton of straw requires somewhat more storage space, and where straw is used, one ton per animal is necessary. A ton of sawdust occupies 144 cubic feet and a ton of baled shavings requires 160 cubic feet for storage. If sawdust is used, about one and one-half tons per animal are required. The quantity of shavings needed per animal is from one-half to three-fourths of a ton. A cow eats from three to five tons of silage yearly and one cubic foot of silage weighs forty pounds. (See silage table page 35).

The proper amount of storage space may be easily provided, if all details are carefully worked out on paper first.

Appearance

Since the dairy barn is one of the most costly buildings on the farm and will last a considerable period of time, its general appearance can be made to add much to the farm. It is just as easy to combine the essential features that have been mentioned in a building that is strikingly attractive in appearance as in an unsightly one.

From the viewpoint of advertising, the appearance of the dairy barn means much to the dairyman. It is almost universally accepted by the public as an index of the success of the business, the quality of the products, the quality of the dairy herd, and the efficiency of the dairyman himself. A barn of pleasing appearance will also enhance the value of the farm and be a source of pride and satisfaction to the owner.

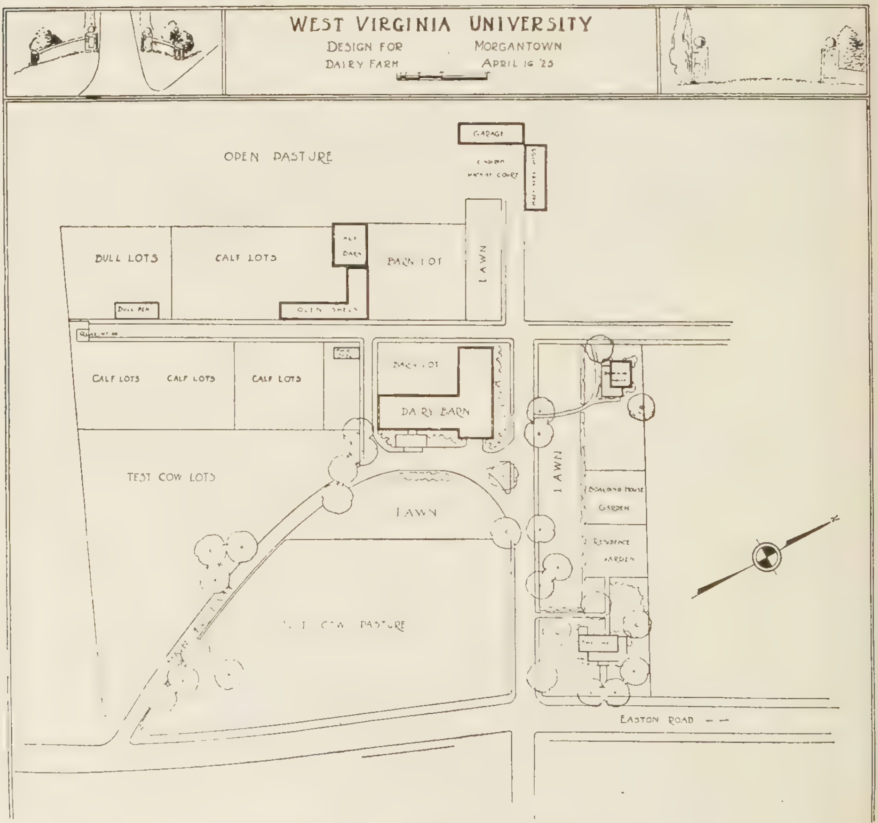


Fig. 1.—Only by planning for the future in a definite way as shown in this dairy farmstead landscape plan can a convenient and attractive farmstead layout be brought about.

THE DAIRY BARN

In Relation to the Farmstead

The location of a particular building always brings up the question of farmstead planning. The present building arrangements on most farms are the result of accident rather than planning. The enterprising farmer, however, will plan for the years to come and outline the future building program for his farm in such a way as to make a convenient and sane arrangement eventually.

Many farms are "overbuilt." On the farm where the buildings are too large and too expensive, the upkeep is excessive. Such a condition always detracts from the selling value of the farm.

Well planned buildings fit the farm and are located in such relation to each other that the arrangement is not only sightly but convenient. It is only by planning a development for the farmstead to be worked out over a long period of years that the present haphazard building arrangement on farms can be changed to a pleasing and convenient layout without undue cost. Figure 1 shows a well planned farmstead.

Location

In planning a dairy barn, its location should be chosen with reference to the other buildings and pasture and feed lots. The barn can be located with reference to other buildings so that the work may be done with a minimum of time and travel; yet not so close as to seriously increase the fire risk. Every saving of 100 feet of unnecessary travel in each trip to the barn means a saving of 14 miles of travel per year, thus showing that **convenience** in location is worthy of due consideration.

If the barn can be located so that its long axis extends north and south a maximum amount of sunshine will pass through the barn during the day. This is of material aid in regulating barn temperatures.

A well-drained site will prevent dampness in the barn and feed rooms, particularly, and tend to eliminate mud in the barn yard. Dampness in any barn, particularly a dairy barn is undesirable. In locating the barn, it will also prove of advantage to consider the location with reference to the water supply.

Foundation and Floor

The best construction material for foundations and floors is concrete, because of its cheapness, durability, ease of construction, and sanitary features. The foundation should be at least ten inches thick,

have a good footing at the base, tapering to eight inches at the ground line, and run about eight inches even thickness on up to the top of the wall. The concrete should be carried up above the ground level one to two feet. Often the concrete wall is carried high enough so that the window frames are placed directly on top of the wall. (See illustration on this page.) This makes a wall back of the cows that is rat proof, is easily cleaned, and places the sill of the barn above the damp ground to prevent rotting.

A good foundation will have proper footing and extend well below the frost line. For footings a 1-3-6 mix may be used. Reinforced concrete requires at least a 1-2-4 mix. In floors where a finish course is to be applied, a 1-2½-5 mix is the common one for the first course. When a single course floor is to be laid a 1-2-3 or a 1-2-4 mixture will be satisfactory. (By a 1-3-6 mix is meant one part of cement to three parts of sand to six parts of gravel.)

Framing Construction

The results of the study that has been made of farm building problems in the past few years are clearly evidenced in the evolution of the type and style of framing used for modern farm buildings. In the pioneer days of American agriculture, the structures, largely of necessity, were built from hand hewn timbers, and have given rise to

The foundation should be carried well above the ground line with sills and window framing placed directly on top of the wall.

A modern dairy barn under construction showing the method of framing.

a type of framing that has persisted even to the present day. As may be seen from the illustrations of framing construction (Figures 2, 3, and 4) the old type of timber framing is wasteful of space and materials, which at prevailing prices means unnecessary cost.

In comparing the plank framing types of construction with the timber style of framing it may be noted that with plank framing the central portion of the barn is free from obstruction of any kind. This gives much more storage space and reduces the labor of storing and removing hay and straw. Less material is needed for plank frame construction than for timber framing.

The two common types of roof framing, the "Shawver truss" and "braced-rafter," are shown in Figures 3 and 4. In the Shawver truss framing, a truss such as is shown in Figures 4 and 5 is placed in the construction every ten to fourteen feet. This gives a structure that is light yet extremely strong.

With the braced-rafter framing, the kind of framing shown in Figure 3 is carried out on each set of four rafters throughout the entire length. If properly constructed, braced-rafter framing is strong, and gives more room than the truss framing. It also has the advantage of requiring less lumber in construction.

Figure 6 shows typical side and end framing construction.

The Stable

HEIGHT

The commonly accepted height for the dairy stable is from eight feet to eight feet and six inches. A height greater than this increases the difficulty of maintaining a proper temperature difference between the inside and outside air in cold weather. A stable lower than this increases the difficulty of carrying on the work in the stable as well as makes lighting a more difficult problem.

When carriers are used in the barn, a ceiling lower than eight feet and six inches is likely to cause difficulty, since the tracks must drop about six inches below the ceiling. With a low ceiling and a raised feed alley, the use of such labor saving devices would be inconvenient.

WIDTH

The dairy stable should not be designed to house more than two rows of cows, since this requires heavier framing, more expense, and

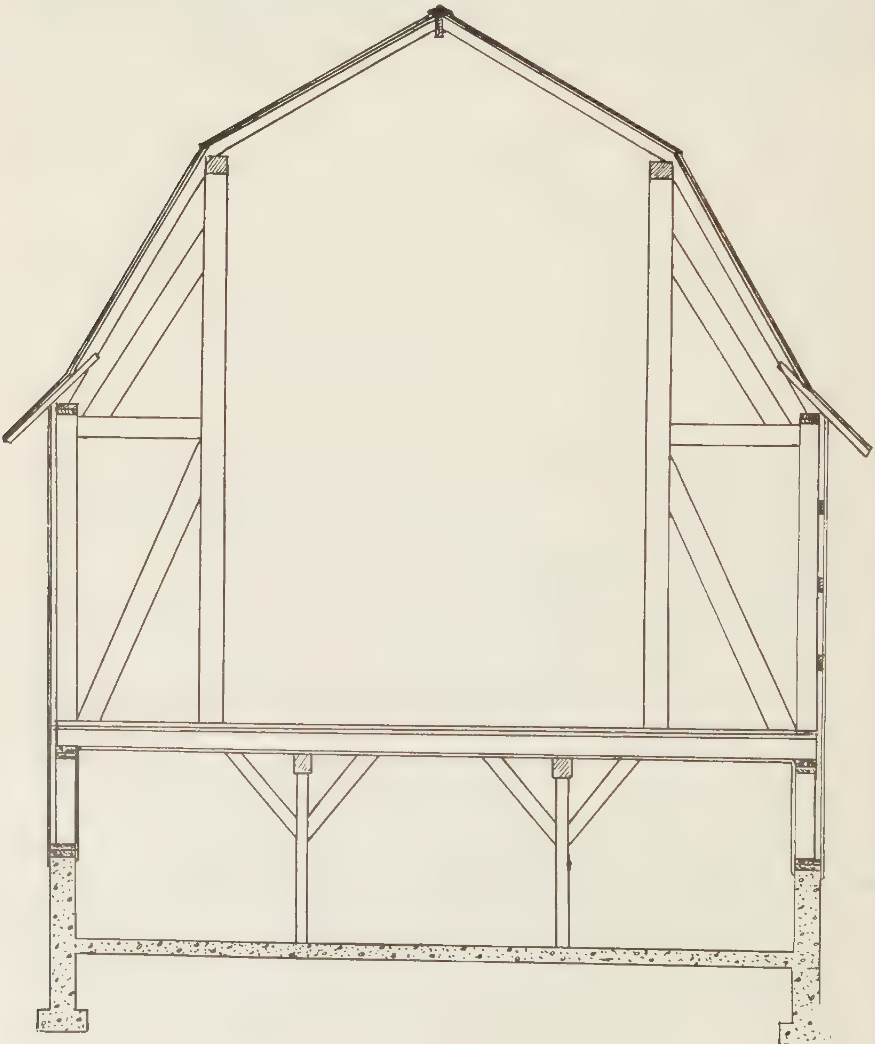


Fig. 2.—Timber barn framing.

makes lighting, storage, and ventilation difficult. For this reason, the width of the stable varies from 32 to 38 feet, depending upon individual preferences and the interior arrangement. Figures 7, 8, 9, and 10 illustrate typical dimensions for 32 and 36 foot barns with either "face-in" or "face-out" arrangement. Varying types of mangers, stalls, and stall floors are also shown.

Where the cows face in it will be noted that the alleyway behind them is made as nearly five feet in width as possible, and this dimension should be considered as a standard one under the conditions named. This gives needed width to the alley preventing crowding and possible injury, and is also a sanitary feature, in that it prevents the walls from becoming fouled with manure.

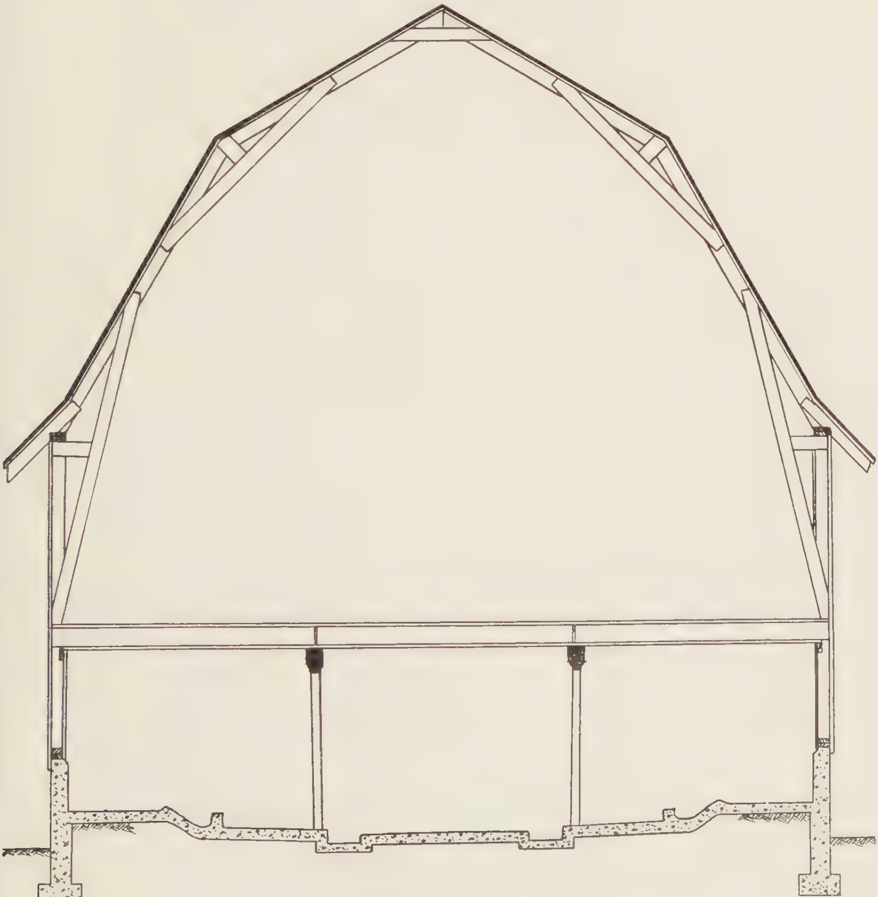


Fig. 3.—Braced-rafter framing.

ARRANGEMENT

The most economical arrangement of cows in the stable is in a double row. This is true for convenience in feeding, cleaning, milking, efficient utilization of floor space and doing general barn work. There are two arrangements, however, commonly referred to as the "face-in" and "face-out" arrangements. Which one the dairyman chooses will depend largely on the type of dairying he is practicing and upon his personal preference.

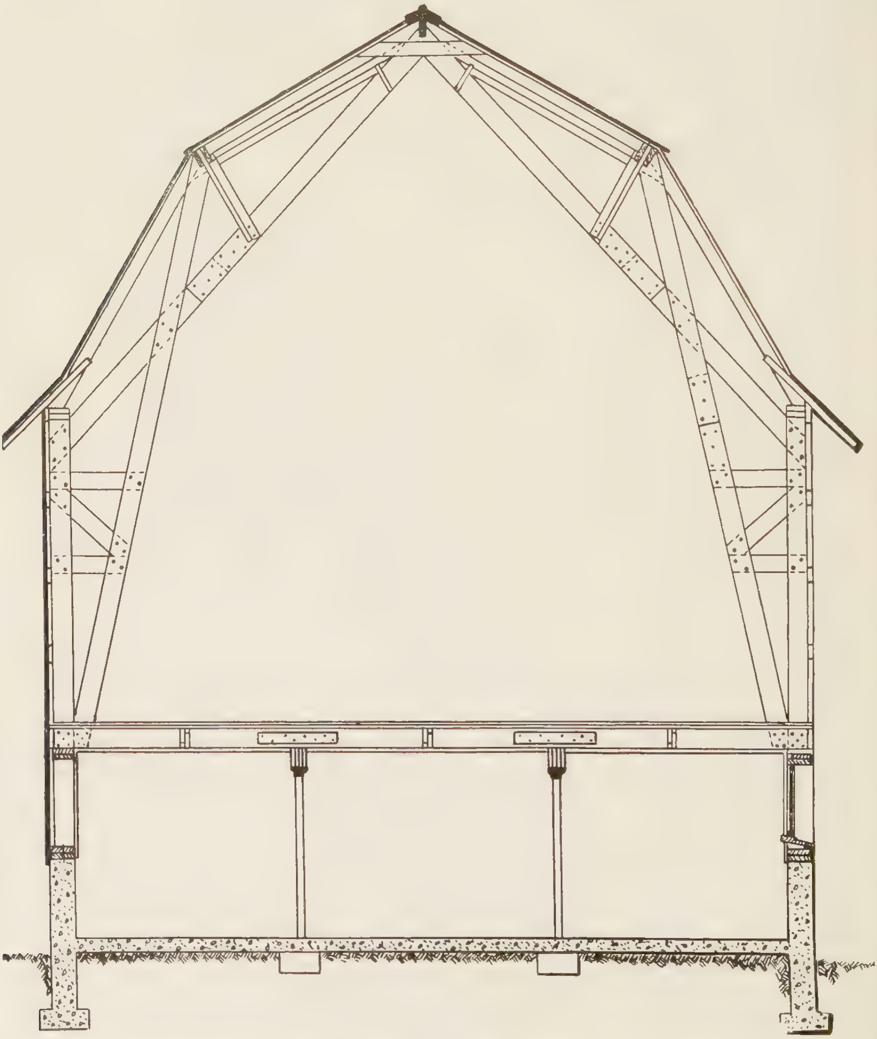


Fig. 4.—Shawver truss framing.

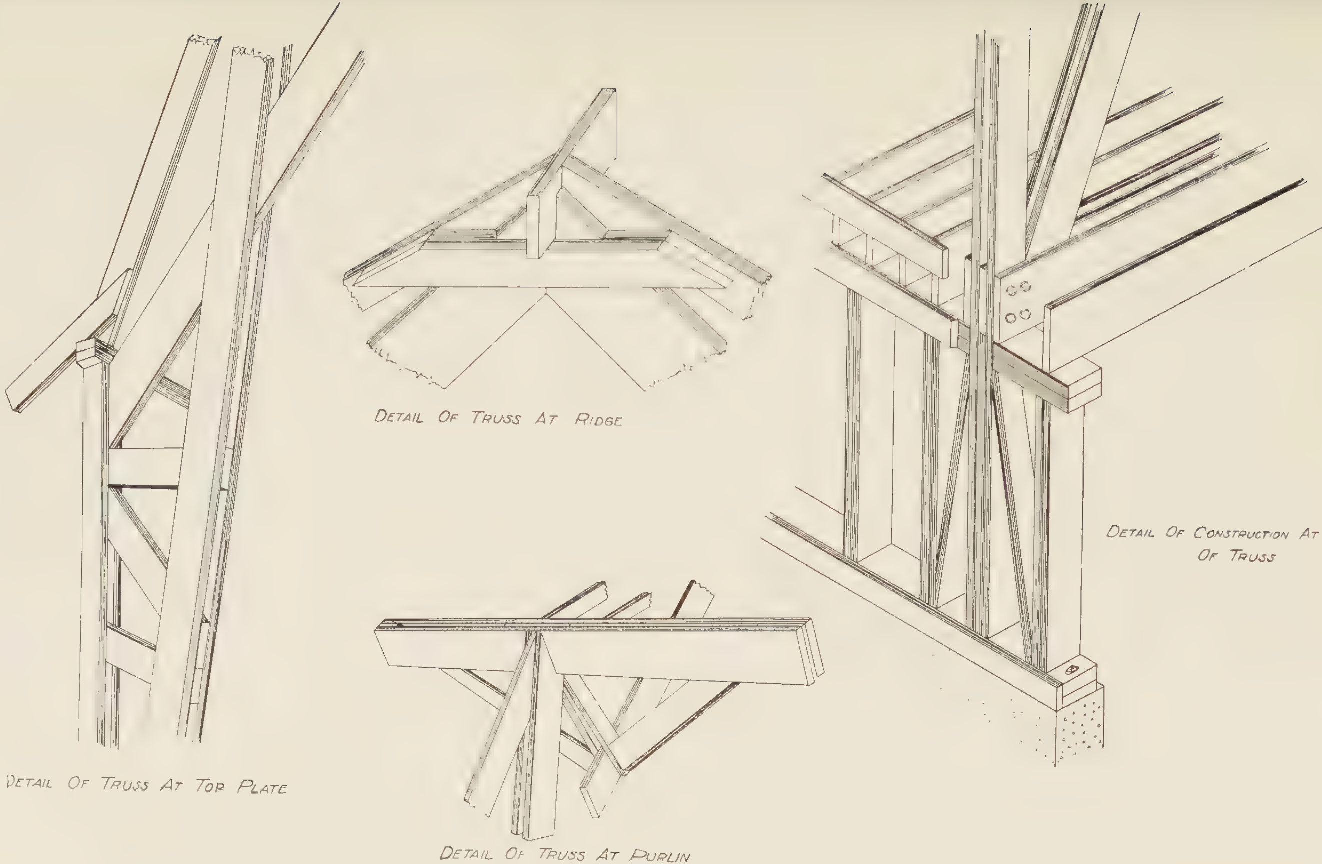


Fig. 5.—Details of Shawver truss framing.

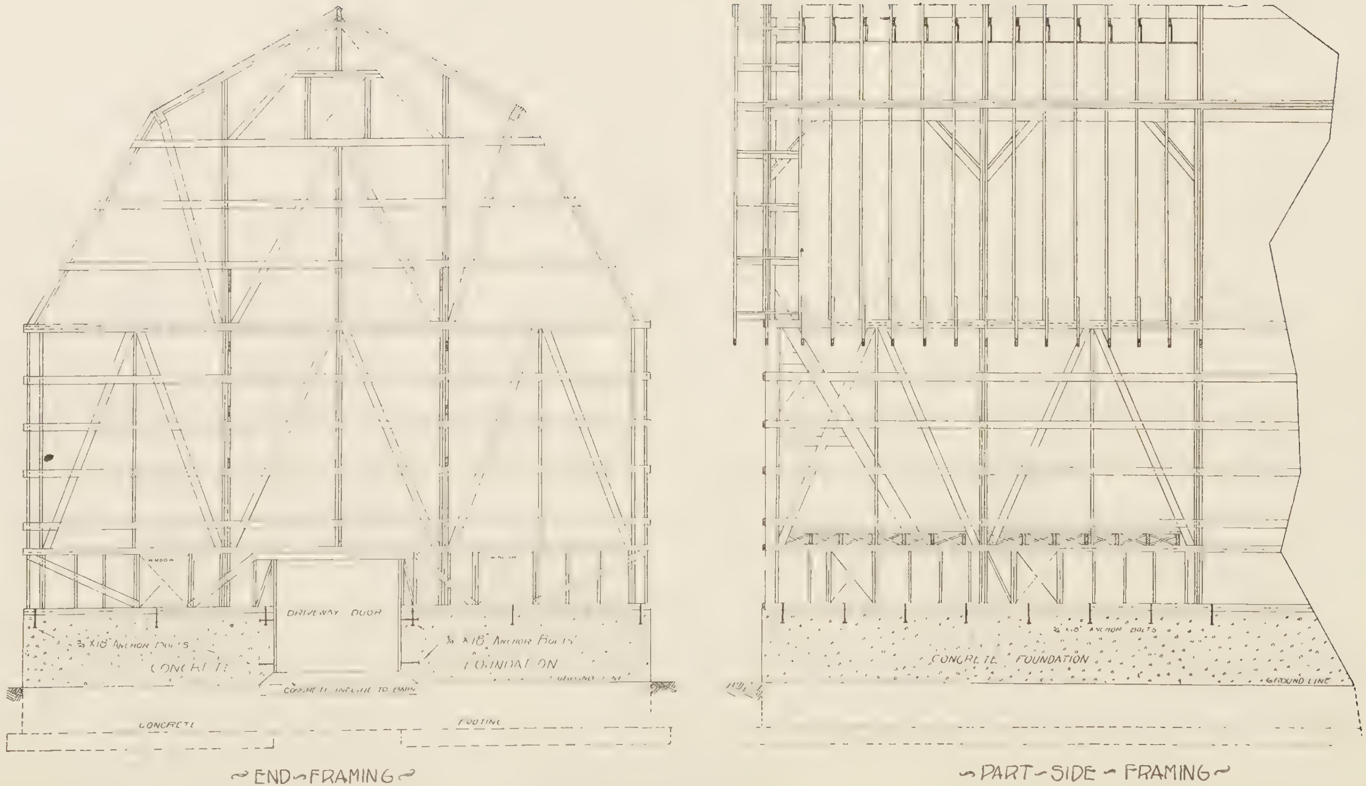


Fig. 6.—Typical side and end framing.

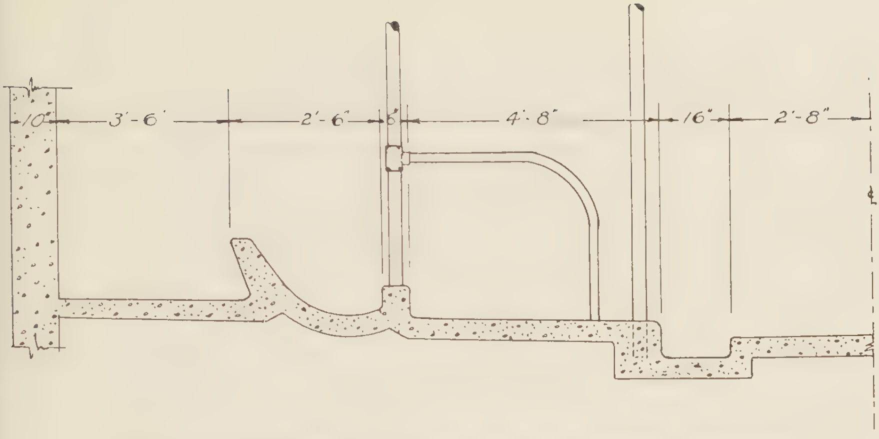


Fig. 7.—Cross section of a 32-foot barn with "face-out" arrangement.

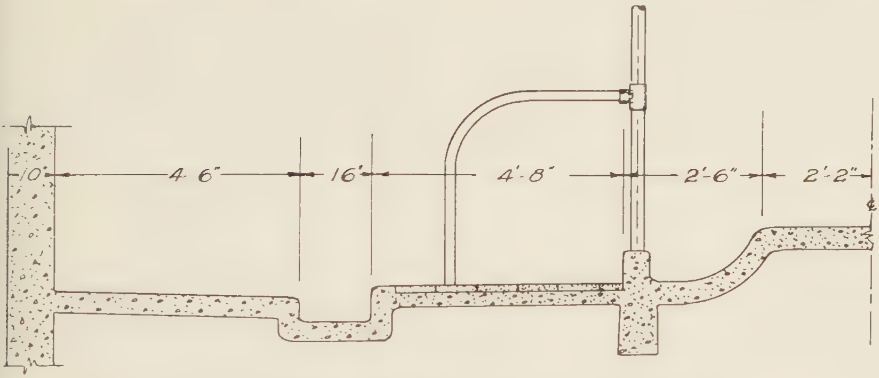


Fig. 8.—Cross section of a 32-foot barn with "face-in" arrangement.

The advantages commonly offered for the face-in arrangement are:

1.—More time is spent in feeding than in cleaning, and the cows may be fed from one alley.
2.—Sunlight on the gutter has a beneficial sanitary effect.
3.—There is better light for milking.
4.—Ventilating system is more easily installed.
5.—There is less confusion in letting cows in and out.
6.—Supporting posts can be placed more conveniently.

The advantages given for the face-out arrangement are:

1.—Manure may be cleaned from one alley directly into manure spreader or manure carrier.
2.—More work is done behind the cows than in front.
3.—Sunlight on manger aids in manger sanitation.
4.—Livestock on display looks better from the rear.

5.—Cows do not have to be separated for entrance into the barn.
6.—There is less danger of spread of disease.
7.—Walls not as likely to become dirty.

The most important factor to be considered in interior arrangement is convenience. Whether the dairyman chooses the "face-in" or the "face-out" arrangement, should depend upon which arrangement makes the most economical utilization of labor, the type of dairying practiced, and the dairyman's own personal preference.

THE STALL

Because of the varying sizes of the individual animals within the breed, and the differences in size among the breeds, it is impossible to give any standard stall dimensions. After measuring 100 individuals and taking careful observations on 1,000 more in various states,

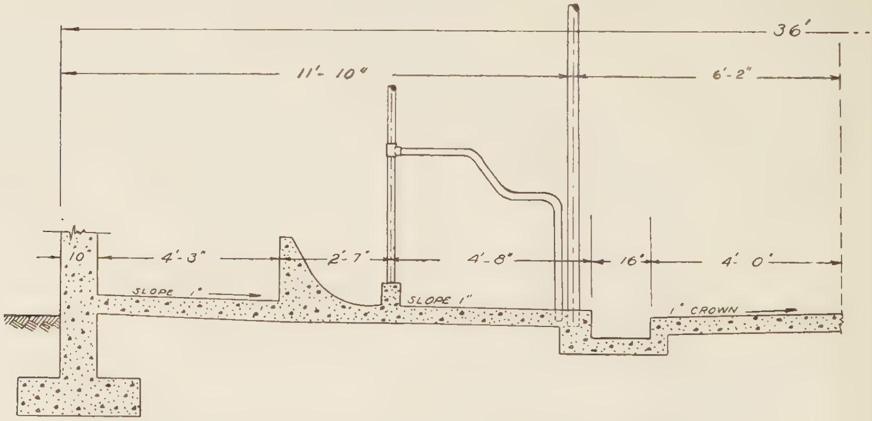


Fig. 9.—Cross section of a 36-foot barn with "face-out" arrangement.

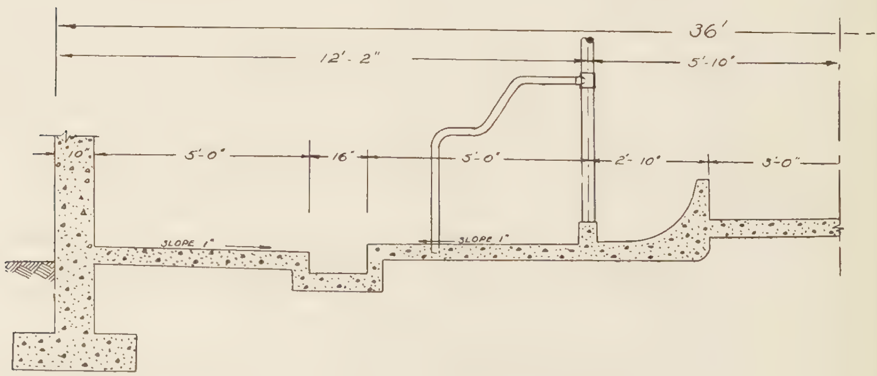


Fig. 10.—Cross section of a 36-foot barn with "face-in" arrangement.

The interior of a modern dairy barn is free from unnecessary obstructions, well lighted and ventilated, and easily kept in a sanitary condition. Compare with arrangement shown in the picture on page 4. The barn shows the "face-in" arrangement.

the following table was prepared by M. A. R. Kelley, United States Department of Agriculture, and presented before the American Society of Agricultural Engineers as evidence bearing upon this problem.

TABLE 1.—Platform Dimensions for Cow Stalls.

Breed	Width of Stall	LENGTH OF PLATFORM		
		Small	Medium	Large
Holstein	3′6″-4′0″	4′-10″	5′-2″	5′-8″
Shorthorn	3′6″-4′0″	4′-8″	5′-0″	5′-6″
Ayrshire	3′6″-3′8″	4′-6″	5′-0″	5′-6″
Guernsey	3′4″-3′6″	4′-6″	4′-10″	5′-4″
Jersey	3′4″-3′6″	4′-4″	4′-8″	5′-0″
Heifers	2′9″-3′2″	3′-8″	3′-10″	4′-2″

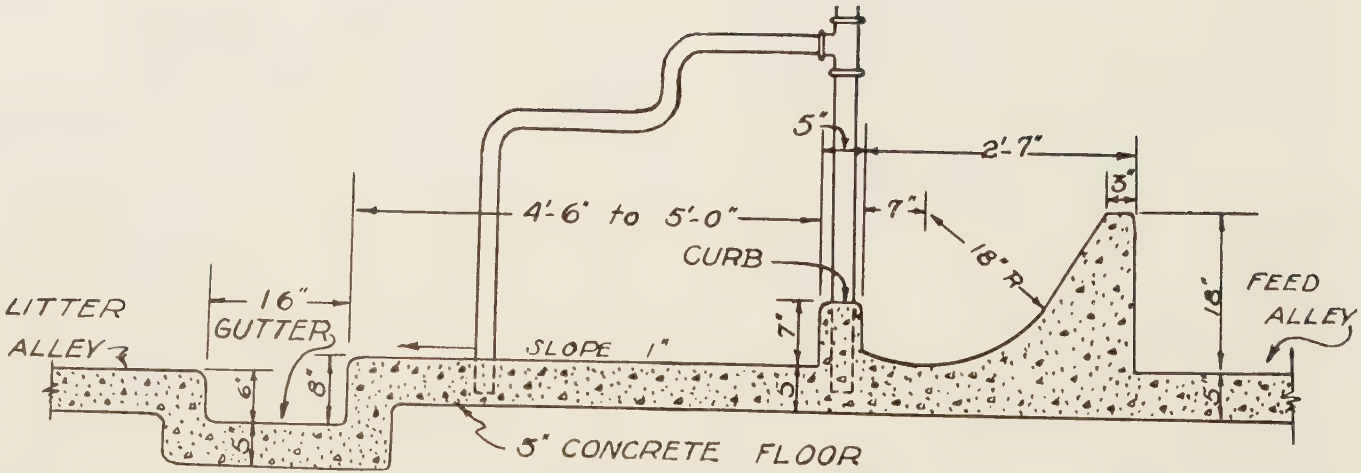


Fig. 11.—Details of stall construction.

The average width of stall and the one most commonly used is 3 feet and 6 inches. For milk cows it should not be less than this because of the danger of udder injury and lack of room for milking.

The length of the stall is even a more variable quantity. The best plan is to make the platform long enough to accommodate comfortably the breed kept and then by the use of adjustable stanchions regulate the length for the individual animals. In almost every case in modern construction, iron pipe has replaced wood for use in stanchions and stall partitions. Stall partitions are always desirable but the old type wooden partition is bulky, unsightly, and unsanitary. (See illustration on page 29).

The concrete stall platform, roughened sufficiently to give good footing and prevent slipping, will tend to prevent injury. Sometimes a depression of one inch extending back from the curb sixteen inches to eighteen inches is left in the platform. This allows the cow to stand on the level and also aids in keeping the bedding in the stall. (See Figure 11). Where cork brick or wood blocks are used on the stall platform, there is added comfort for the cow, since the wood floor is considerably warmer than concrete, and somewhat easier to stand on.

THE MANGER

Because of the large number of manufacturers of dairy equipment in the United States and the comparatively large number of types of mangers which were in existence, differing only in minor details to make them individualistic, the American Society of Agricultural Engineers made a definite effort to standardize manger forms. This resulted in the adoption of the standard manger types shown in Figure 12.

The essentials of a good manger as set forth by the society are:

1.—All corners should be round to facilitate cleaning.

2.—The manger should be free from cracks and crevices.

3.—The surface of the manger should be smooth.

4.—Continuous mangers are preferable, as they are easier to clean and easier to construct.

5.—Mangers should have drains with sufficient slope to drain well. A slope of $1\frac{1}{2}$ to 2 inches in 100 feet is sufficient. Drains installed so that they may be easily cleaned are preferable.

6. Concrete manger divisions are not desirable, as there are too many corners to keep clean.

7.—Manger divisions should be removable or hinged to aid in cleaning.

8.—The width of the manger should not be less than 24 and preferably 30 or 32 inches.

9.—The bottom of the manger should be 1 to 2 inches higher than platforms on which the cows stand.
10.—The curb should never be less than 6 inches higher than than bottom of the manger.
11.—The width of the curb may be 4 inches, if not over 7 inches high; 5 inches or more wide, if a built-up curb is used; and six inches wide when the supporting columns are in line with the stanchions. The height of the manger front is preferably 24 and never more than 30 inches.
12.—Curved manger bottoms concentrate feed and save water when used for watering.

There are enough types of mangers shown in the standard forms adopted that the dairyman may choose the one best suited to his conditions. If the type shown in Figure 12 with a width of 20 inches is used, it should always be used with a raised feeding ally as indicated by the dotted lines.

THE GUTTER

Various types of gutters have been used in the past in dairy barn construction. The type of gutter used is more important than would seem at first thought, since it has an important bearing on the sanitation of the barn. A gutter must be not only sanitary, but safe as well. It should not be so wide as to tempt the cow to jump across nor so deep as to make it difficult for the cow to get out of the stall.

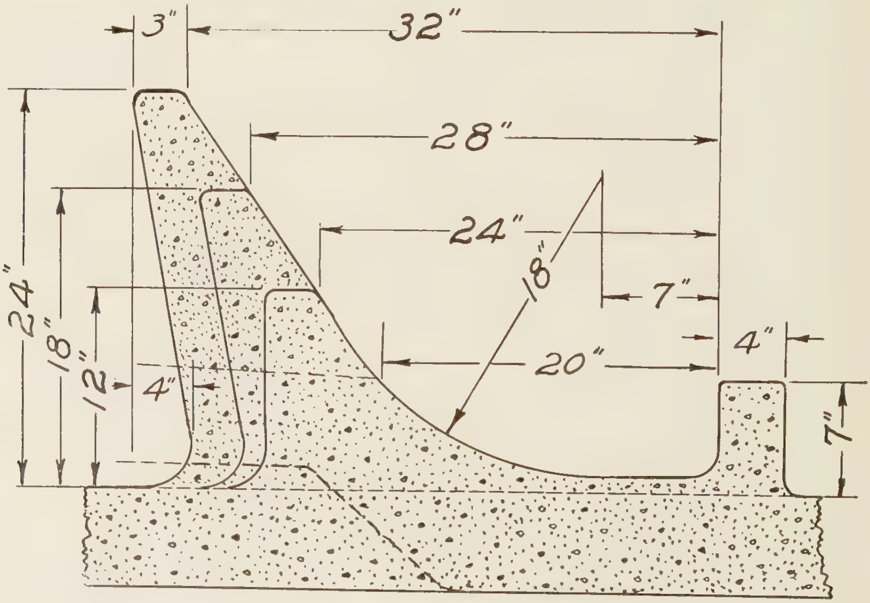


Fig. 12.—Standard manger details.

The best gutter width is 16 to 18 inches, and the depth ought always to be at least 6 inches. A shovel the same width as the gutter will make cleaning easy. This is an argument for the 16 to 18-inch gutter, since a shovel large enough to fit wider gutters is cumbersome, unwieldy, and heavy to handle when filled. It is desirable that the litter alley be lower than the stall floor, thus making it much easier for the cow to back out of the stall. A slope of one inch to 40 feet is sufficient for the gutter to drain well. The bedding will absorb most of the liquid manure but drains will be needed for such drainage as may be necessary and to facilitate washing out the gutters with water.

WINDOWS

There are two methods of determining the glass area necessary to give proper light in the dairy stable. One method, commonly in use, is to allow 4 square feet of glass area per cow. The other is to allow 1 square foot of glass area for every 25 square feet of floor space. The choice of which method to use is often governed by local ordinance requirements. The windows should be as evenly distributed throughout the barn as possible in order to give light in all parts of the stable. This arrangement also adds to the exterior appearance. Practically all ordinances for the production of "A" grade milk require four square feet of glass area per cow.

An excessive amount of window space in the stable makes temperature regulation difficult.

The windows are often placed so low that cows in crowding each other or in fighting flies will break the glass. Also, windows that are placed too low in the wall do not give a desirable distribution of light in the center of the barn.

The common type of window used is the single sash, hinged at the bottom so that it may be opened from the top and thus prevent direct drafts. A six or nine-light sash is commonly used, with glass ranging from 8 by 12 to 9 by 14 inches. Sometimes a six-light sash is used, with 8 by 12 inch glass. The advantages offered for its use are: (1) It has just the glass area required per cow (4 sq. ft.); (2) It will fit between the studding without cutting them.

Where a sash of such size is used one window for each cow housed will be sufficient.

Where single sash windows opening from the top are used, some effective type of window stop will be necessary. Where only chain and hook are used, broken windows are a very common occurrence.

WALLS

A tight wall construction is essential to a successful ventilating system and control of barn temperatures. As has been stated, the con-

crete wall is often carried above the floor level at least one to three feet; the latter figure where cows face in. A good wall construction will be tight and warm. Probably the best wall construction is as follows from outside to inside in order: siding, building paper, sheathing, studding, and matched ceiling throughout. Metal lath and concrete plaster may be used instead of the ceiling where desired.

VENTILATION

The purposes of ventilation in a barn are to provide fresh or pure air for the animals to breathe, to remove the foul air from the stable, to remove moisture given off in breathing, to prevent foul odors, and to assist in regulating barn temperatures. A cow breathes large quantities of air each day, and gives off considerable moisture in addition to carbon dioxide. This, if allowed to collect on the walls, causes dampness and increases the danger of colds and pneumonia. Ventilation, therefore, in addition to providing fresh air aids in keeping the barn dry and warm.

Interior view of braced-rafter roof framing, showing metal outtake flues and insulation which are part of the ventilating system.

There are two types of ventilating systems commonly in use in dairy barns. One is called the Rutherford system; the other, the King system. The King system or some modification of it is the more commonly used in the United States. In this system the fresh air inlets open at or near the ceiling and the foul air out-takes open near the floor (See Figure 13).

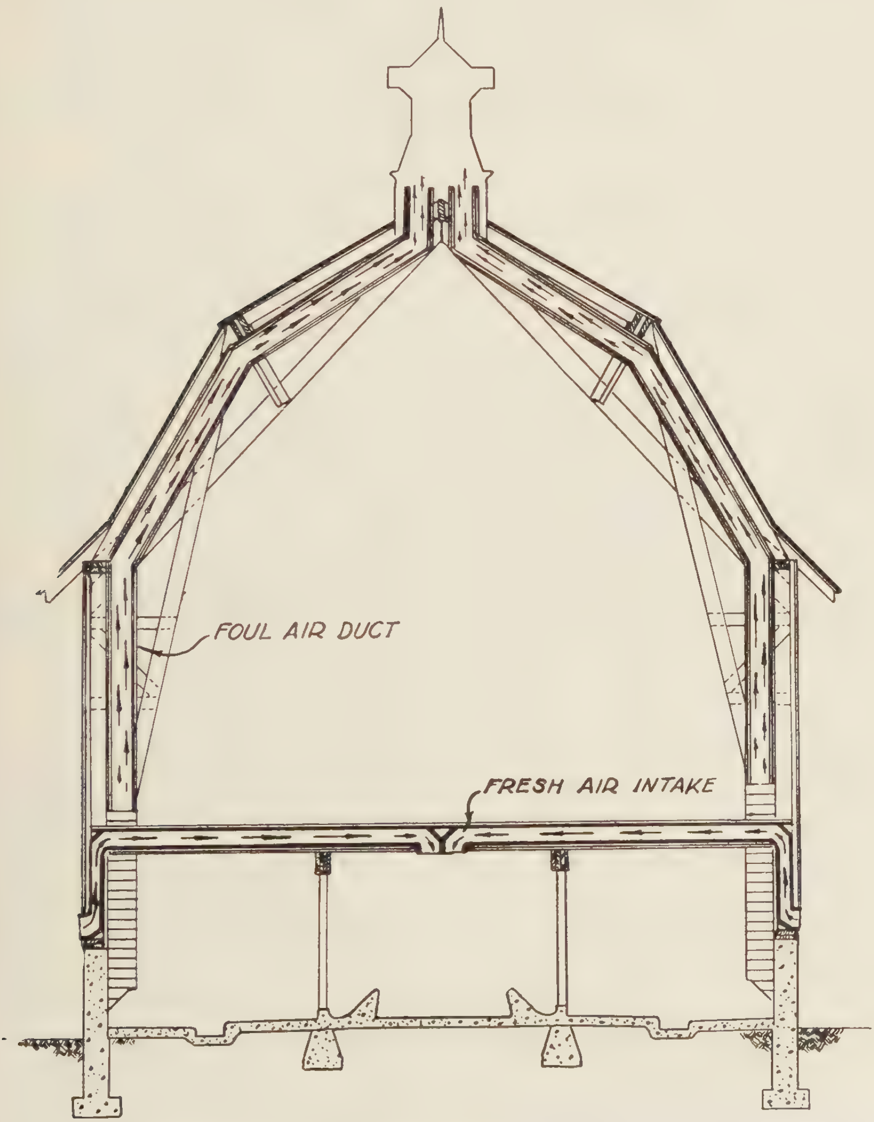


Fig. 13.—Diagram of barn ventilation showing inlet and outtake flues.

Flues properly constructed and insulated are necessary to have the system operate successfully. Outtake flues are generally constructed of wood with two thicknesses of matched lumber and building paper between. The flues, if placed inside the line of the studding and rafters, will be warm enough to function properly. Several firms are manufacturing metal flues which work satisfactorily.

Good ventilation requires many more inlet than outtake flues evenly distributed throughout the stable. One outtake every 30 to 35 feet is sufficient. The total area of the inlets should be slightly greater than the total area of the outtake flues. For the system to operate properly it is necessary that all other openings in the barn be closed.

Prof. F. L. Fairbanks of Cornell University, who has recently made extensive tests on dairy stable ventilation says: "We do not know definitely that so-called 'adequate ventilation' increases milk flow or improves the health of the cow. We do know, however, the engineering requirement for moisture removal while maintaining stable conditions that are permissable. I believe that good air in the dairy stable does have a decided influence on the health and production of the animals, and I hope that in due time veterinary medicine, animal husbandry, dairy industry, and chemistry will join hands with agricultural engineering to prove this point."*

Practically all ordinances require at present, however, an air capacity in the stable equivalent to 500 cubic feet per cow.

That so many ventilating systems in the past have been unsatisfactory, has been due to the fact that the systems have not been carefully worked out and the flues properly constructed and insulated.

FLOOR PLANS

Each dairy barn needs individual consideration since each presents so many different problems. This is because the size and plan of the barn depend upon so many factors, all of which are variable on different farms. For this reason, no one plan or set of plans can be devised to meet all needs. The plans shown in Figures 14, 15, and 16 indicate good interior arrangement and conform with the dimensions and essentials of construction which have been discussed. It is very probable, that with slight modification, these plans will meet the needs of many farmers interested in dairy barn construction. If help or information, additional to that herein contained, is desired by anyone considering the building or remodeling of a dairy barn, it may be obtained by writing to the College of Agriculture, Morgantown, West Virginia.

---

*Agricultural Engineering Journal A. S. A. E., Vol. 8, No. 2, Feb. 1927, p. 34.

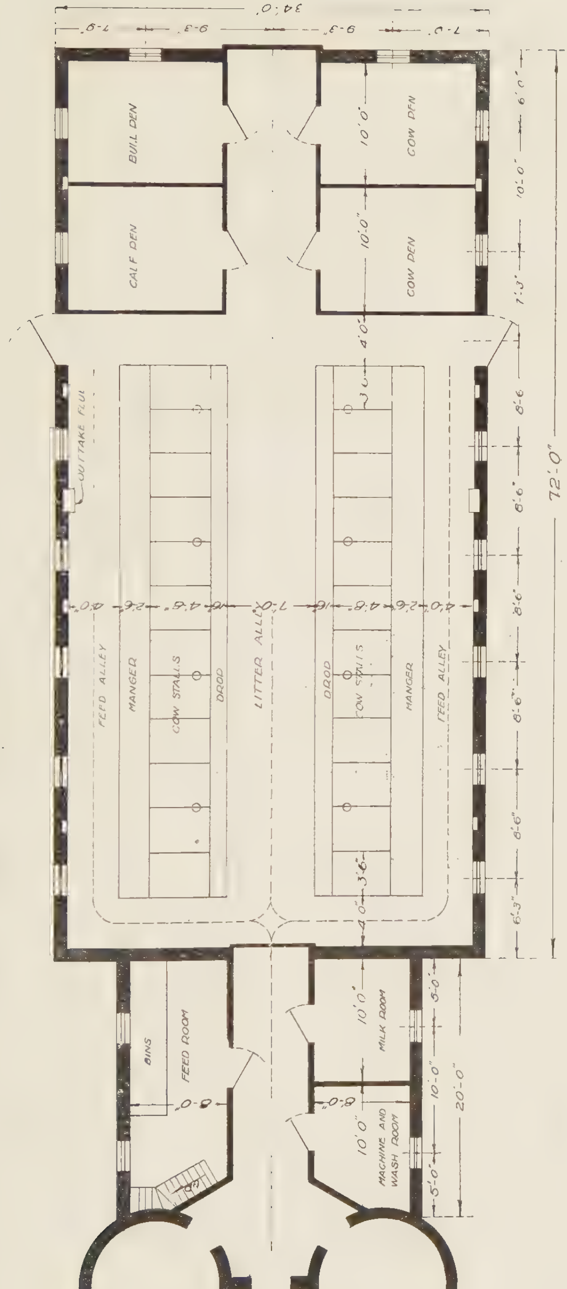


Fig. 14.—Floor plan for a dairy barn housing 24 cows.

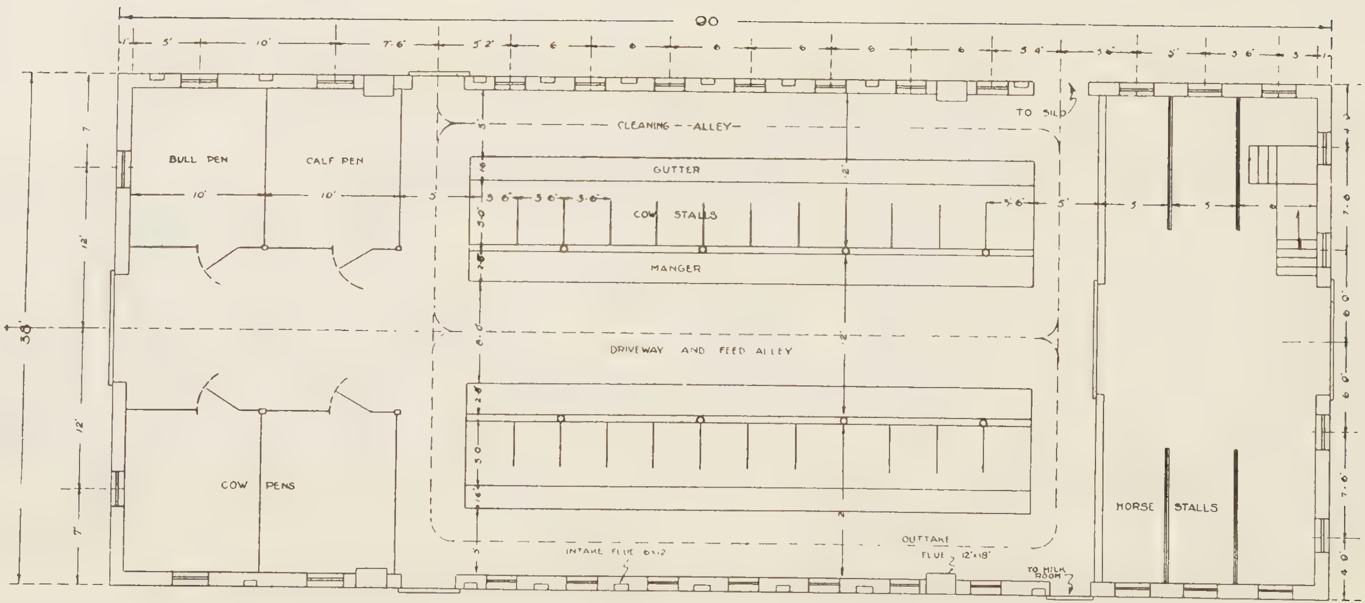


Fig. 15.—Floor plan of a dairy barn housing 24 cows, with central driveway. The horse stable is effectively separated from the dairy stable by a tight partition and sliding door. This is an important sanitary measure and is required in the production of high grade milk.

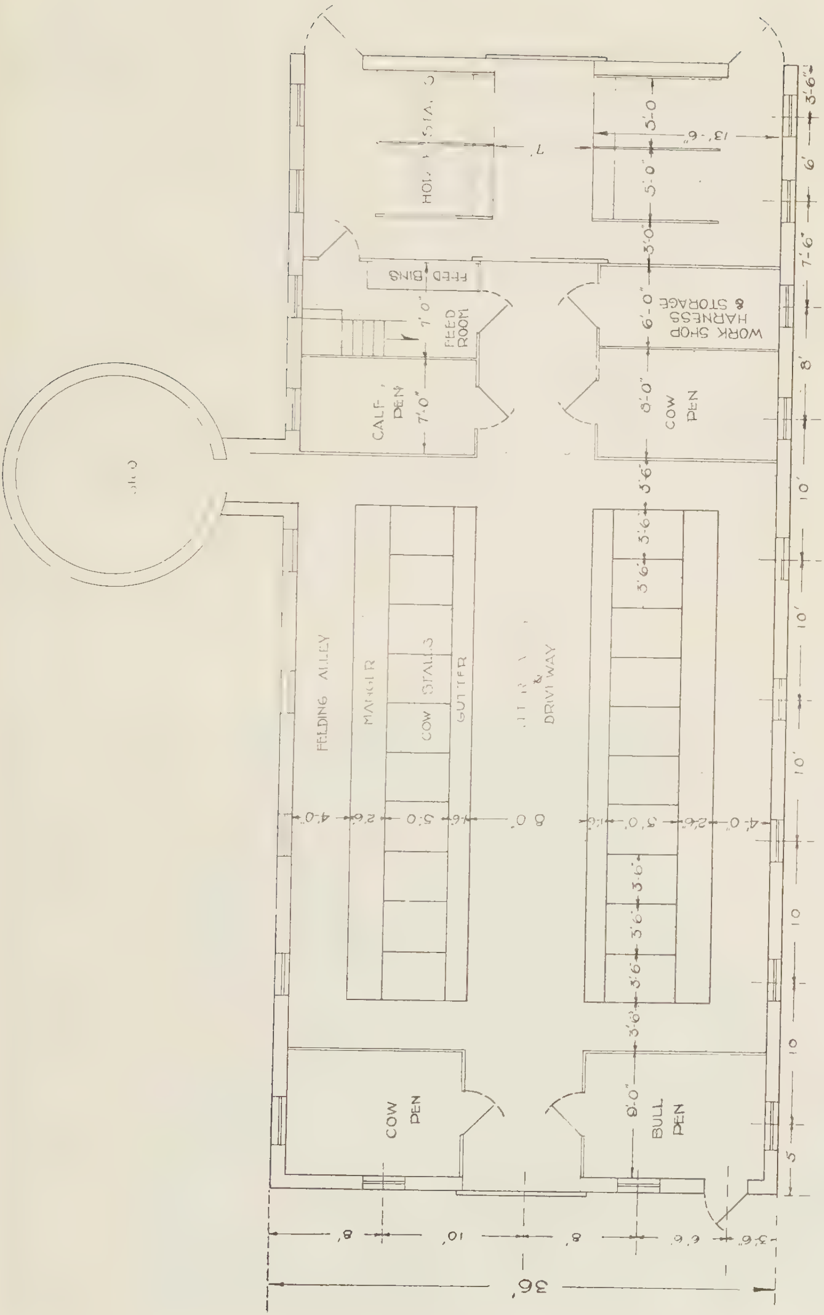


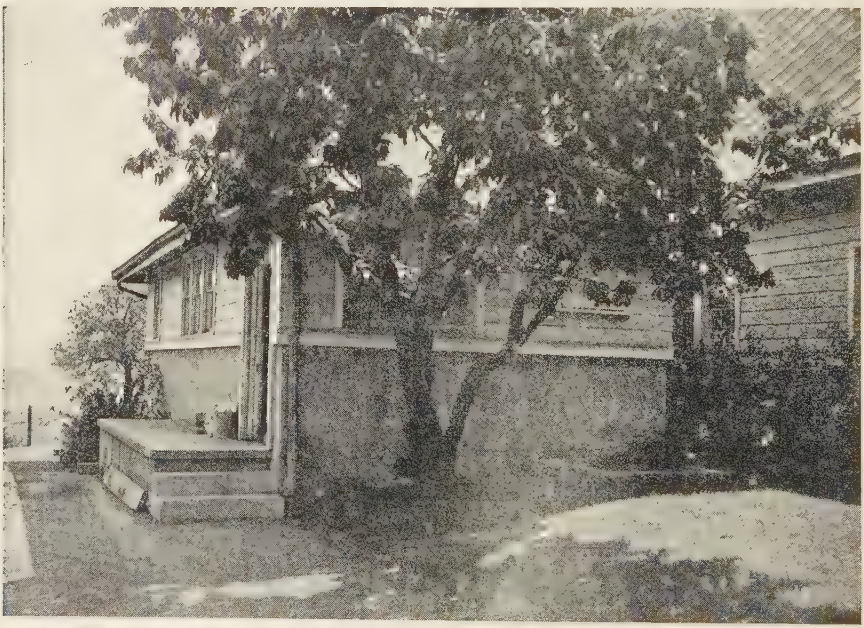
Fig. 16.—Floor plan for dairy and horse barn with the horse stable effectively separated from the dairy.

THE MILK HOUSE

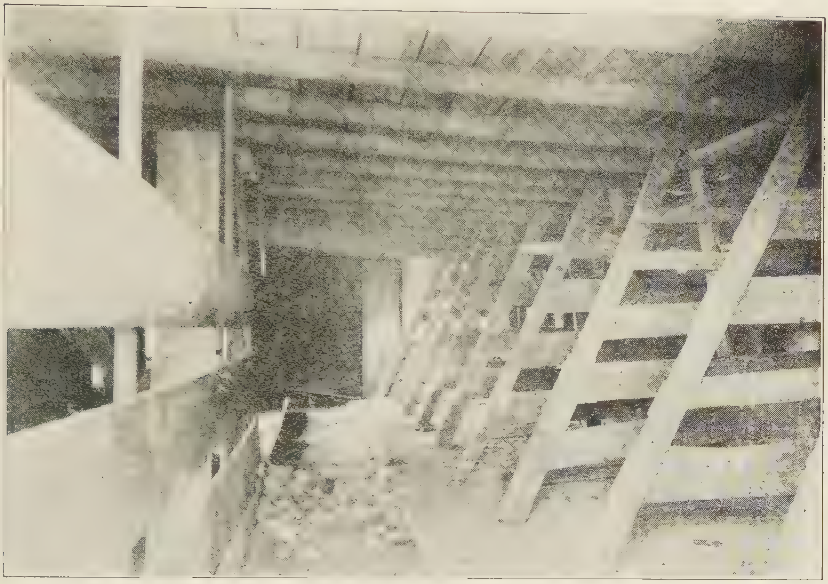
In the production of clean milk, some type of milk house, properly located with reference to the stable, is essential. Milk should be cooled as soon as possible after milking, and be kept at a low temperature until delivery to the creamery. Then, too, the milk house makes it possible to handle the milk entirely away from the dust and odors of the barn. Milk handled in this way is likely to have a low bacterial count.

If the milk house is attached to the barn, it should be separated from it by double doors, both of which should be kept closed. Many ordinances require that the milk house be entirely separated from the barn a specified distance. For convenience, however, the milk house should be located as near the barn as existing ordinances and proper sanitation will permit. Local ordinances vary somewhat and it is always advisable to consult the local ordinance before locating and constructing the milk house.

The standard ordinance governing milk houses, published by the United States Public Health Bureau is as follows: "Milk house or room—Construction: There shall be provided a separate milk house or milk room for the handling and storage of milk and the washing



A desirable type milk house which is connected to the barn by only a passage way.



The all-too-common type of dairy stable or barn which makes milk ordinances necessary.

and sterilizing of milk apparatus and utensils, provided with a tight floor constructed of concrete or other impervious material and graded to provide proper drainage. The walls and ceilings of the milk house or room shall be of such construction as to permit easy cleaning and shall be painted at least once each year or finished in a manner approved by the health officer. The milk house or room shall be well lighted and ventilated and all openings effectively screened to prevent the entrance of flies, and shall be used for no other purpose than the handling and storage of milk and milk products and other operations incident thereto. The cleaning and other operations shall be so located and conducted as to prevent any contamination from one to the other. The milk room shall not open directly into the barn or into any room used for sleeping or domestic purposes.

"Cleanliness and Flies. The floors, walls, ceilings, and equipment of the milk room shall be kept clean at all times. All means necessary for the elimination of flies shall be used."

The Clarksburg ordinance is a good example of the type of ordinance now in effect in West Virginia cities. It reads:

"The building or milk house in which milk is cooled, strained or bottled, or pastuerized, or handled for sale must have an area way between it and any stable, barn, kitchen, or living room, or house,

and this area way must be controlled by two doors. It is desirable that the milk house be separated from the stable and on opposite side from

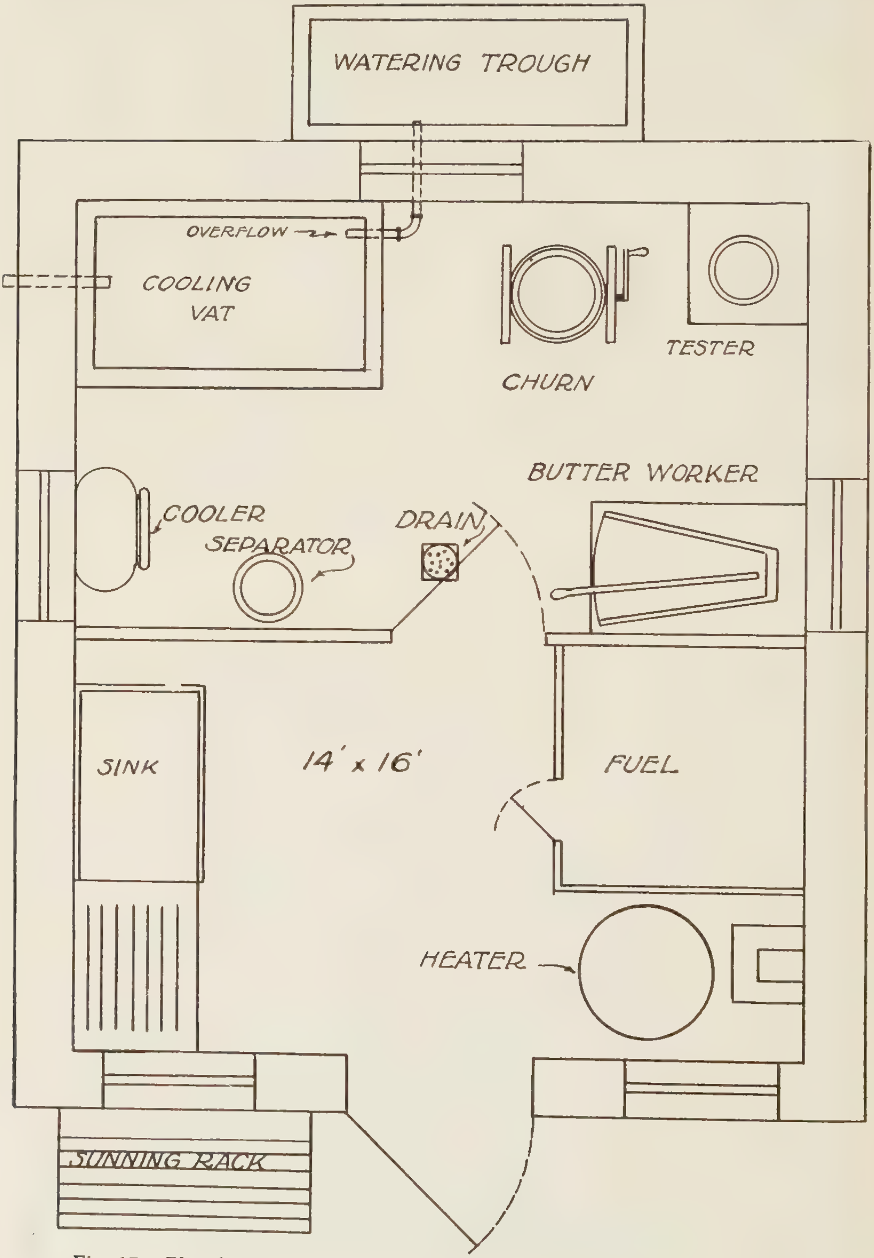
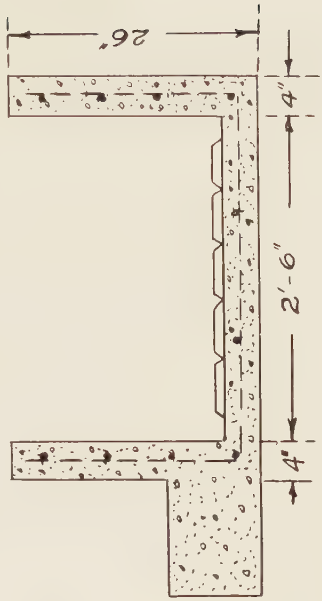


Fig. 17.—Plan for a 14 by 16-foot milk house with the heater and wash room separated from the cooling room.

manure pits or drains and except by special permission by the Physician, no water closet, privy, garbage heap, or manure heap may be maintained within one hundred feet of such milk house or room, and this milk room shall not be used for any other purpose.

"The milk house shall have a non-absorbent floor and smooth tight walls and ceiling. It shall be provided with screens at all windows and doors for protection from flies. It shall be free from dust and objectionable odors and must be kept clean and tidy at all times."

Figure 17 shows a plan for a milk house 14 by 16 feet with heater and wash room effectively separated from the cooling room. The cooling vat shown assumes the use of spring water for cooling.



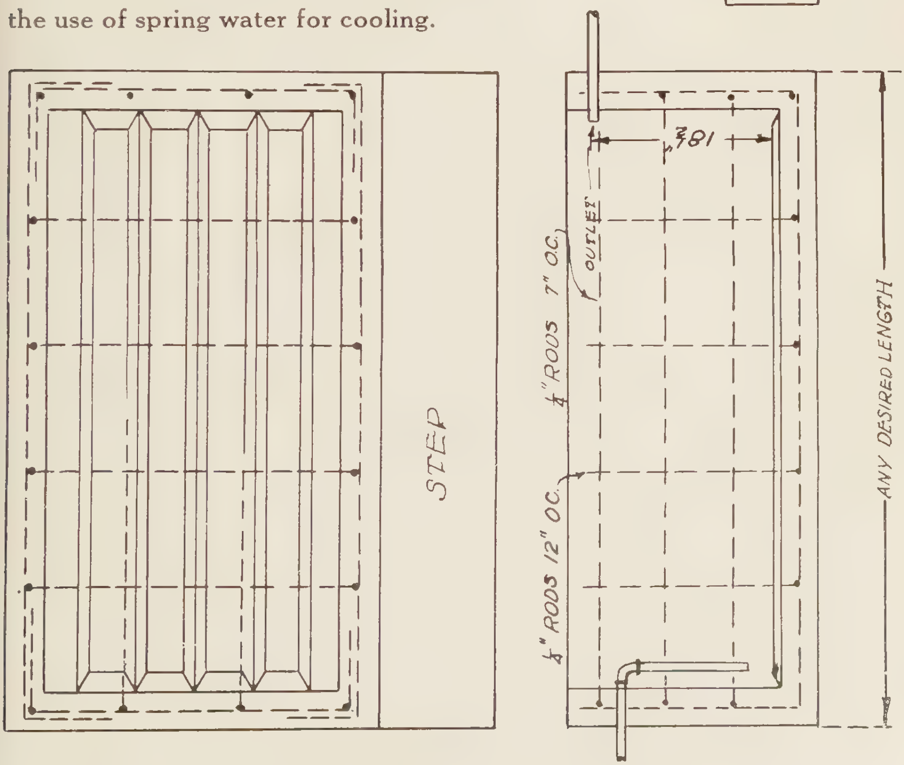


Fig. 18.—Details of the milk cooling vat shown in Figures 17 and 19.

The details of the cooling vat shown in Figures 17 and 19 are given in Figure 18. The watering trough shown in Figure 17 is merely a suggestive use for overflow water.

Figure 19 shows a small, single room milk house adapted to smaller dairies and general farms. This milk house, if properly constructed, meets sanitary requirements and is relatively inexpensive.

In case the farmer wants a very simple and inexpensive method of cooling small quantities of milk or cream, a barrel cooler of the type shown in Figure 20 works satisfactorily. This type of cooler is adapted for use by the small producer, and should not be considered as a satisfactory substitute for the milk house, where milk is produced in quantities sufficient to be marketed as whole milk.

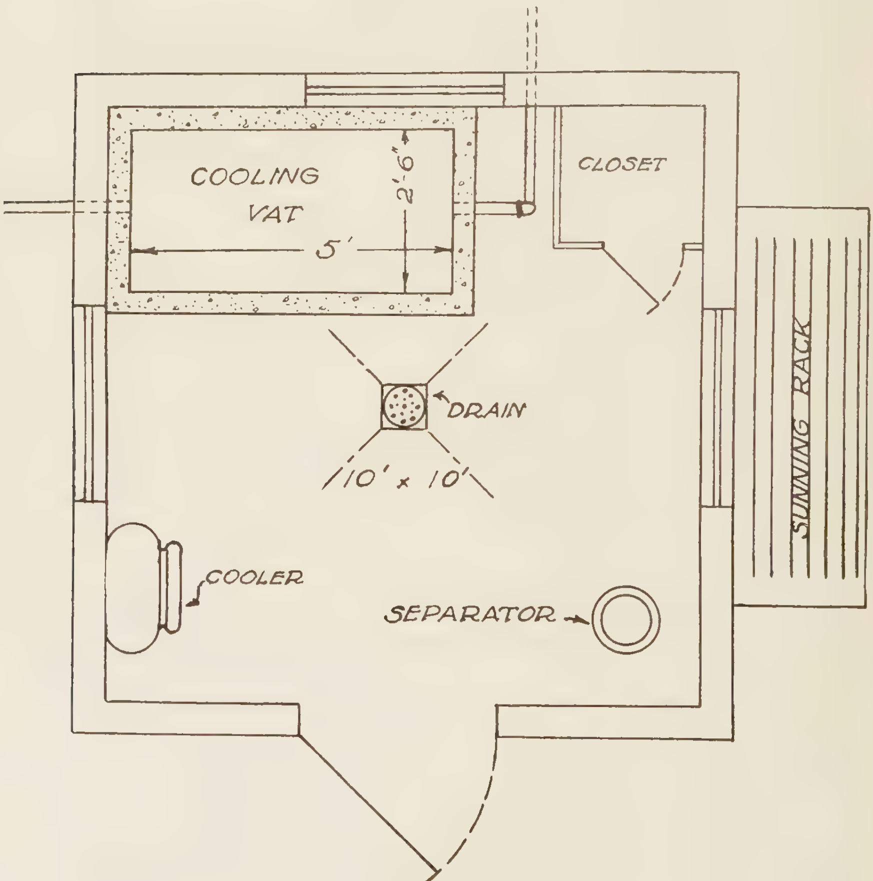


Fig. 19.—Plan for a small, single-room milk house.

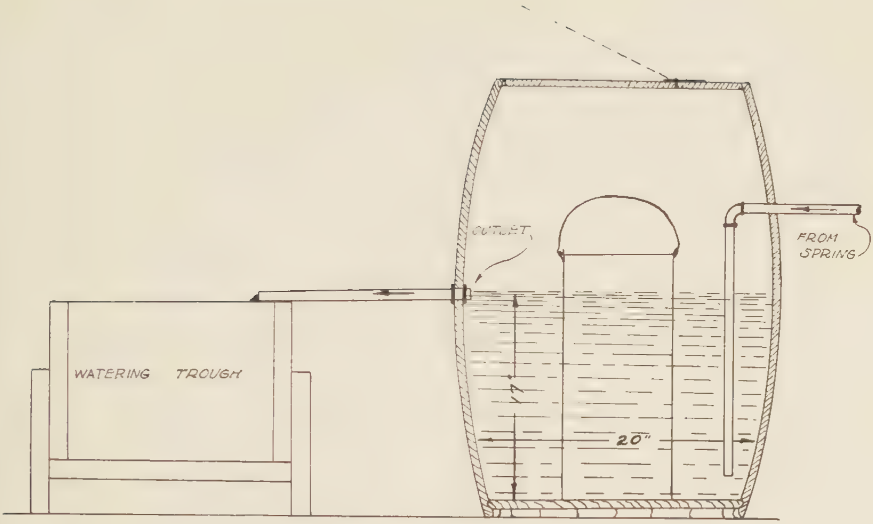


Fig. 20.—Barrel cooler for small quantities of milk or cream.

THE SILO

The value of silage for feeding dairy cows lies in its palatability, succulence, and general food value. Where animals are fed as intensively as dairy cows are for production, a feed such as silage is necessary to keep the cow in good physical condition. Silage is not only the best substitute for pasture, but is also the cheapest. The growth of the use of the silo in dairy and livestock farming is ample evidence of the increasing recognition of the value of silage for feed.

Silos of the following types are now commonly in use: monolithic concrete, concrete staves, concrete block, woodhoop, brick, tile, wood stave, and trench or underground silos.

The essentials of a good silo are:

1.—An impervious wall. That is, a wall which will exclude air and retain the moisture in the silage.

2.—A smooth inner surface so that the silage will settle uniformly.

3.—Sufficient strength to withstand wind pressure from without, and the pressure of the silage from within.

The best location for a silo is a place where a solid and durable foundation can be obtained. It is also to advantage to select as sheltered a location as possible for the silo and to provide some effective type of cover. Convenience of location from the standpoint of feeding is, however, of primary importance.

The foundation may be laid off as shown in Figure 21. It should be at least eight inches in thickness with proper footing. It is difficult to lift the silage from a pit more than two to four feet below the surface. The foundation footing should extend twelve to eighteen inches below the bottom of the pit, and the wall should extend far enough above the surface of the ground to prevent rotting, in case of

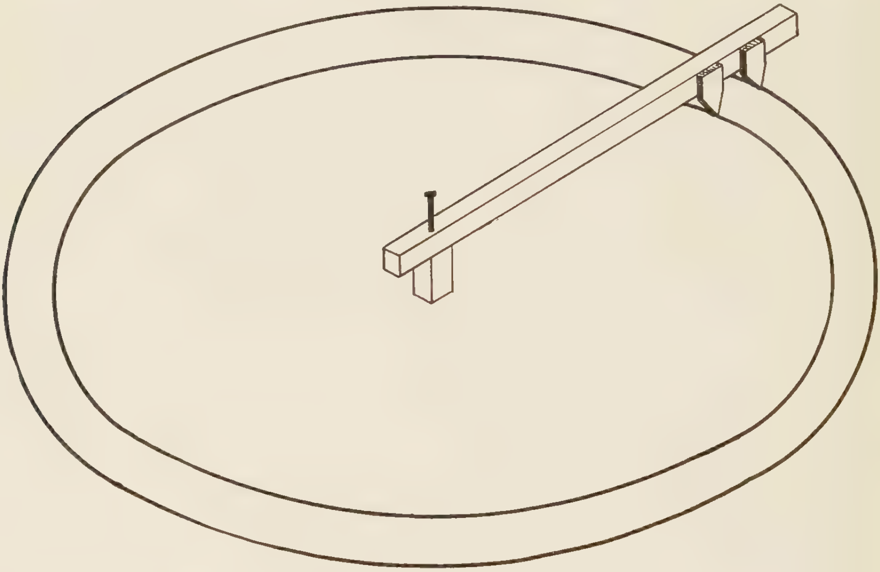


Fig. 21.—Method of laying out silo foundation.

a wooden silo. An offset in the wall on the inside where silo and foundation walls meet interferes with proper settling and causes spoilage.

The concrete foundation of a 1-2-4 mixture, properly spaded in the forms makes a good impervious wall. A tile drain laid to carry off liquids from the silo will remove some pressure and prevent spoilage. A trap may be set in the concrete floor.

If properly constructed, a silo built from any of the materials mentioned will preserve silage satisfactorily. The best plan seems to be to construct a silo of a diameter such that two or three inches of silage may be removed for each day's feeding. In this way a minimum of spoiling occurs.

A tall silo permits the better settling of the silage and results in a lowered percentage of loss through spoiling. There is a tendency to

TABLE 2.—Sizes and Capacities of Silos.

Inside Diameter	Height	Capacity in Tons	Number of Steers Eating 20 lb per Day for 180 Days	Number of Steers Eating 20 lb per Day for 240 Days	Number of Cows Eating 40 lb per Day for 180 Days	Number of Cows Eating 40 lb per Day for 240 Days
10	20	31	16	12	8	6
10	22	33	18	14	9	7
10	24	37	20	16	10	8
10	26	40	22	18	11	9
10	28	44	24	20	12	10
10	30	47	26	22	13	11
10	32	51	28	24	14	12
10	34	56	32	26	16	13
10	36	61	34	28	17	14
12	24	55	30	22	15	11
12	26	58	32	24	16	12
12	28	63	34	26	17	13
12	30	68	38	28	19	14
12	32	74	40	30	20	15
12	34	80	44	34	22	17
12	36	87	48	36	24	18
12	38	94	52	38	26	19
14	28	86	46	34	23	17
14	30	92	50	38	25	19
14	32	100	52	42	26	21
14	34	109	60	46	30	23
14	36	118	66	50	33	25
14	38	128	72	54	36	27
14	40	138	76	58	38	29
14	42	148	80	62	40	31
16	30	120	66	50	33	25
16	32	131	72	54	36	27
16	34	143	80	60	40	30
16	36	155	86	66	43	33
16	38	167	92	70	46	35
16	40	180	102	76	51	38
16	42	193	108	80	54	40
16	44	207	116	88	58	44
18	36	196	110	82	55	40
18	38	212	118	88	59	44
18	40	229	128	96	64	48
18	42	246	136	102	68	51
18	44	264	146	110	73	55
18	46	282	156	118	78	59
18	48	298	166	126	83	63
18	50	316	176	130	88	65
20	36	243	134	102	68	51
20	38	254	142	106	71	53
20	40	281	160	120	80	60
20	42	300	168	126	84	63
20	44	320	182	134	91	68
20	46	340	188	142	94	71
20	48	361	208	146	104	73
20	50	382	212	150	106	75

take care of larger quantities of silage by increasing the height of silos rather than the diameter. If a sufficient capacity cannot be obtained in a silo of fair diameter and a height of 36 to 40 feet, it is better to build two silos than one too large in diameter. A very good practice with large dairies is to build one large and one small silo, use the silage from the larger silo for winter feeding and the silage from the smaller one for summer feeding.

Table 2 shows the capacities of silos of various sizes.

The wood stave silo is still most commonly found although it is being replaced to some extent by the more durable masonry silos. The wood stave silo owes its popularity to the fact that it combines the essential desirable features of a silo, with comparatively low initial cost.

Wood silos are especially adaptable for tenant dairymen, since such silos may be moved, if necessary, without great difficulty. For the dairyman who is permanently located, however, some type of masonry silo is probably the most economical investment in the long run. The appearance and advertising value for the farm of such a silo is also in its favor.

The vitrefied tile silo is becoming very popular on farms where permanence is desired. It has several points which recommend it, among which may be mentioned the following: it is durable, easily constructed, neat appearing, and acid proof.

MANURE DISPOSAL

The value of stable manure in helping to maintain the fertility of the soil is generally recognized. The waste occasioned through leaching or seepage and heating in the heap is a loss which the farmer cannot afford to overlook. From the viewpoint of sanitation in and about the dairy stable, little discussion is necessary to show the danger of allowing manure accumulations to remain.

City ordinances usually govern the conditions under which milk is retailed within city limits, and the conditions under which it is produced, including the proper disposal of manure accumulations. Cities more and more are taking an active part in such problems through legislation. The ordinance of the City of of Clarksburg states: "Manure shall be removed from the stable twice a day, to a distance at least 50 feet from the stable and from the source of water supply used for washing milk vessels and for other purposes about the milk house. The place or places at which manure is deposited shall be approved by the dairy inspector."

A concrete manure pit helps to conserve valuable plant food.

The growth in knowledge as to the value of all the fertilizing elements in manure, and the need for sanitary methods, if clean milk is to be produced, has brought about the adoption of safe and profitable methods of caring for the droppings in the stable. Probably the best of these is an arrangement whereby the manure may be emptied directly into the spreader and hauled and spread on the fields as soon as the spreader becomes full.

Many progressive dairymen, however, prefer to haul out manure in the slack season when they can thus use their labor to best advantage. In order to do this concrete manure pits are constructed into which the manure is placed until such time as it can be hauled to the fields. The concrete pit prevents seepage of liquids from the manure, and in a covered concrete pit, manure retains a much higher percentage of its fertilizing value than when thrown in a heap in the open.

A manure pit is not excessively expensive and it is certain that the returns on the investment in increased fertilizing value of the manure, in sanitation about the stable, and in the cleanliness of the milk produced, warrant it. (See Figure 22.)

There is still need for study as to the proper location of the manure pit with reference to handling the manure, economy of labor, elimination of odors, etc.

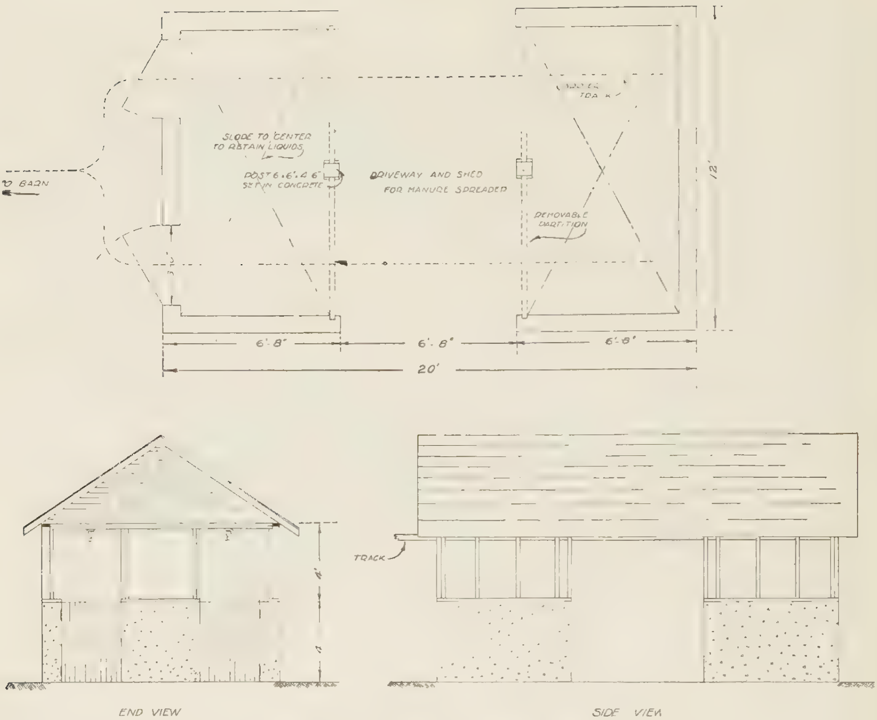


Fig. 22.—Plan for a concrete manure shed or pit.

THE SAFETY BULL PEN

The tendency of dairymen to keep bulls until two or three years of age and then dispose of them is not a good policy from the standpoint of breeding dairy cattle. A sire of good breeding, with ancestors of proven worth, is a great asset in building up a herd. One cannot breed up the best herd if he disposes of his bull before it has reached the time in life when its true value as a sire can be demonstrated.

In order to encourage dairymen to keep their bulls longer and thereby build up their herds properly, a safety bull pen, such as is shown in Figure 23, is suggested. With this pen there need be little handling, and by feeding the bull and opening the door from the feed alleyway, no danger is encountered. A "sneak" may be provided in the front of the pen by leaving one of the fence bars out. This makes it possible for a person to get out of the pen very quickly without having to open the gate, and at the same time does not materially weaken the pen.

The operation of the gate behind the breeding rack makes it possible to take care of breeding with practically no handling. After

service, the bull may be forced from the breeding pen by pushing the gate over toward the bull pen.

Such a pen is desirable for all bulls, and becomes necessary when a bull becomes dangerous, as otherwise, even though he is a highly bred and desirable sire, he will have to be disposed of before the influence of his breeding is shown in the herd.

MINOR EQUIPMENT

The Breeding Rack

The breeding rack is an important item of equipment on the dairy farm. Its use makes it possible to breed small heifers or cows to heavy bulls, or large cows to small bulls. The breeding rack, as may be seen from Figure 24, is easily constructed and costs very little. On most farms there is enough material lying around to make a very satisfactory rack of this description. The cost of raising a heifer until it enters the herd is considerable, and the use of the breeding rack eliminates much of the risk of injury that might otherwise result. The rack should be located conveniently near the barn and bull pen.

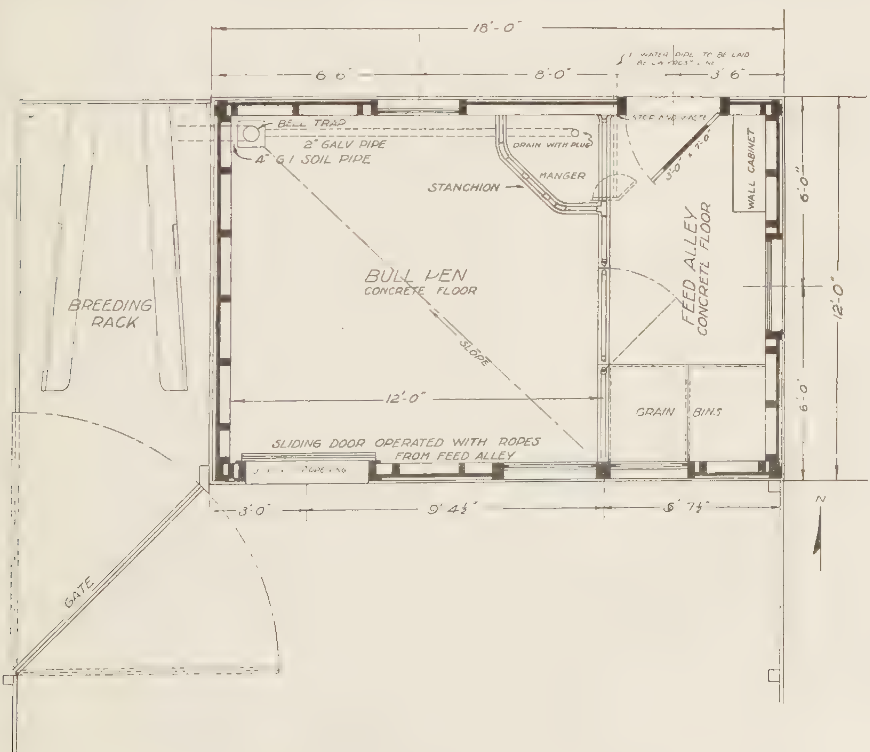


Fig. 23.—Plan showing the details of a safety bull pen.

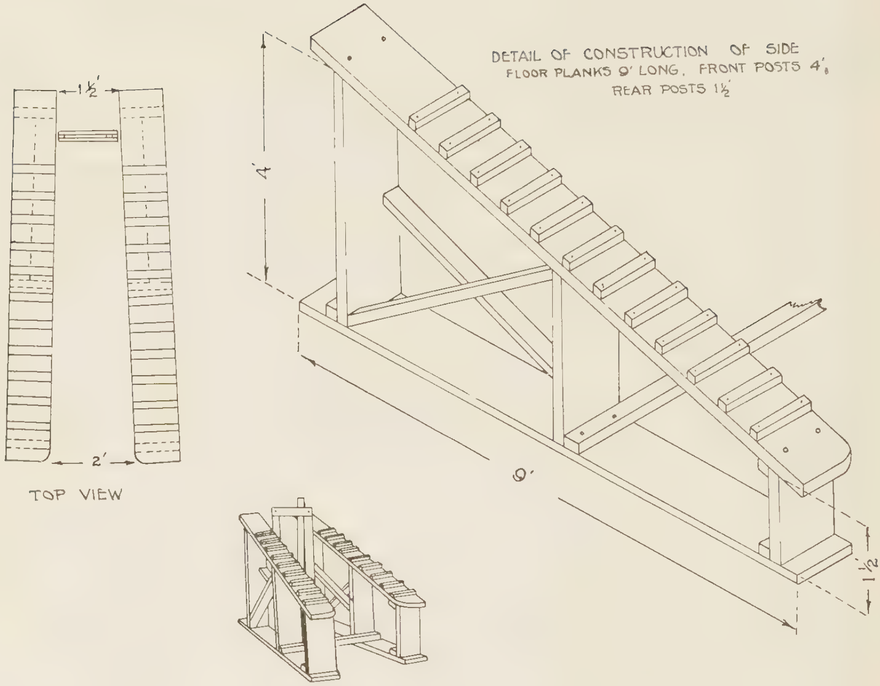


Fig. 24.—Showing the construction and details of the breeding rack.

Cattle Stocks

The device shown in Figure 25 often saves much difficulty and prevents possible injury in handling animals for purposes of dehorning, trimming hoofs, and general treatment. It is common practice to throw the animals in trimming the hoofs, but there is always an attending possibility of injury. The use of the stocks eliminates this danger, especially where valuable animals are being handled.

A canvas sling attaches to the rollers and passes under the barrel of the animal. With this device the animal is lifted gently from its feet, making it possible to trim the hoofs quickly and effectively, or administer other types of treatment.

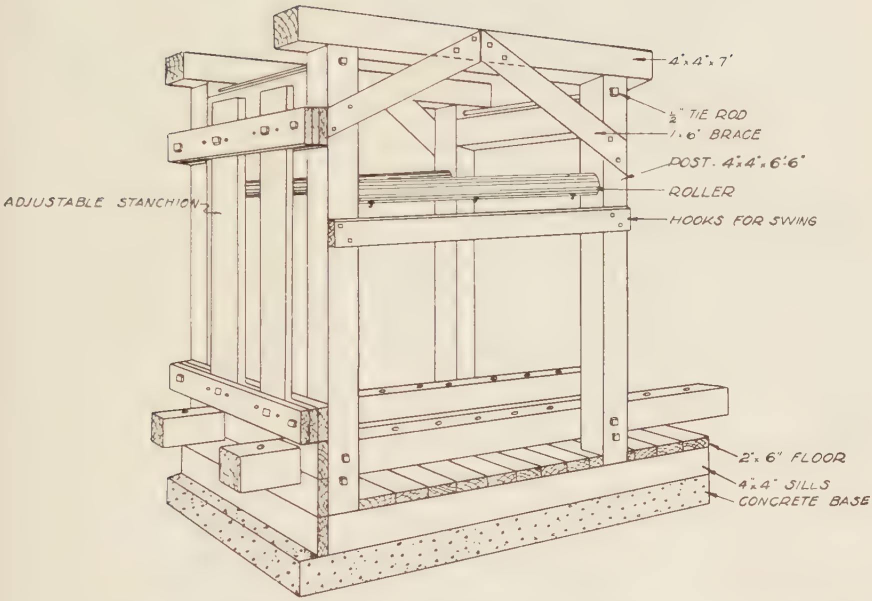


Fig. 25.—Cattle stocks constructed as shown above have proved very satisfactory.

A Home-Made Milk Cart

Where the cooling vat or milk house is some distance from the barn, or where milk is transported from the milk house to a loading platform at the road, some type of cart for transportation often saves the time of hitching and unhitching a horse for the purpose of hauling the milk these short distances.

A cart such as is shown in Figure 26 is a very handy article of equipment, and is easily constructed. The axle is placed in such a way that most of the weight of the load may be set forward of it. In this way, when the handle is lifted so that the front supports clear the ground, the weight of the cans will carry the cart along on level ground.

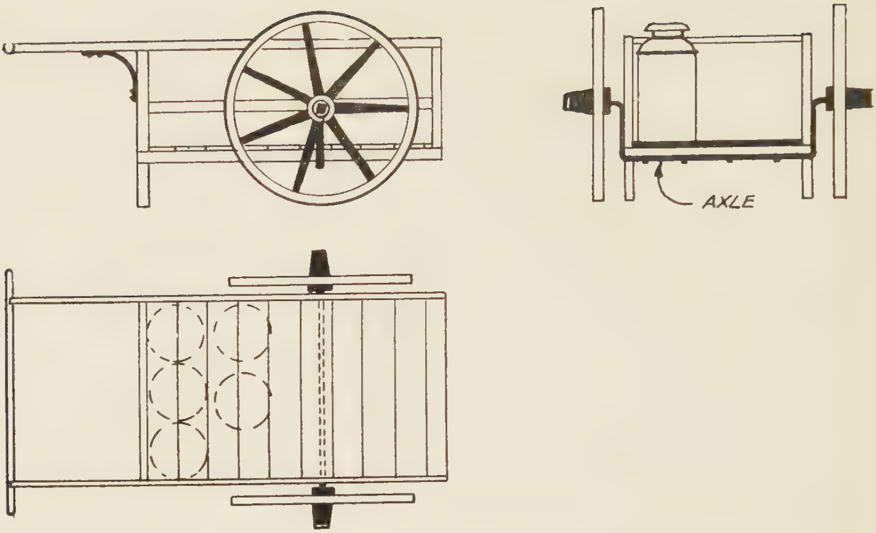
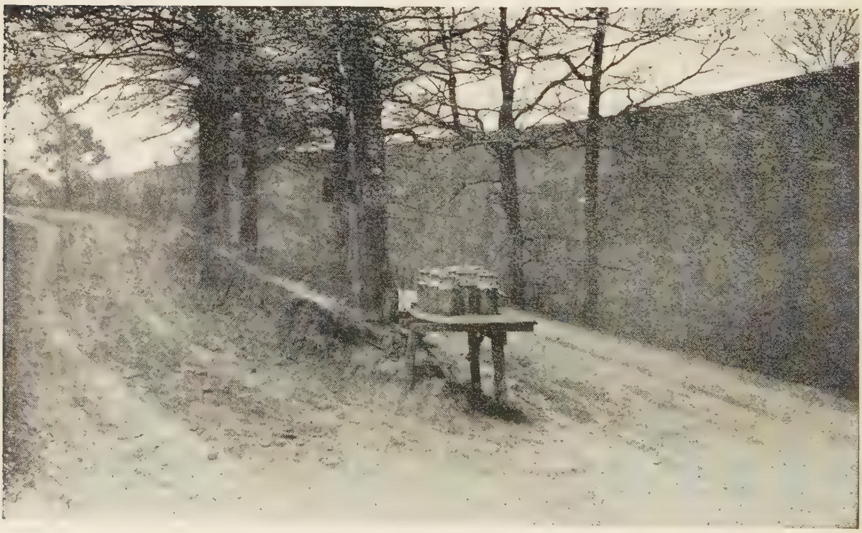


Fig. 26.—A simple, home-made cart.



A common type of roadside loading platform that is unattractive and does not afford protection for the milk. Compare with Figure 27.

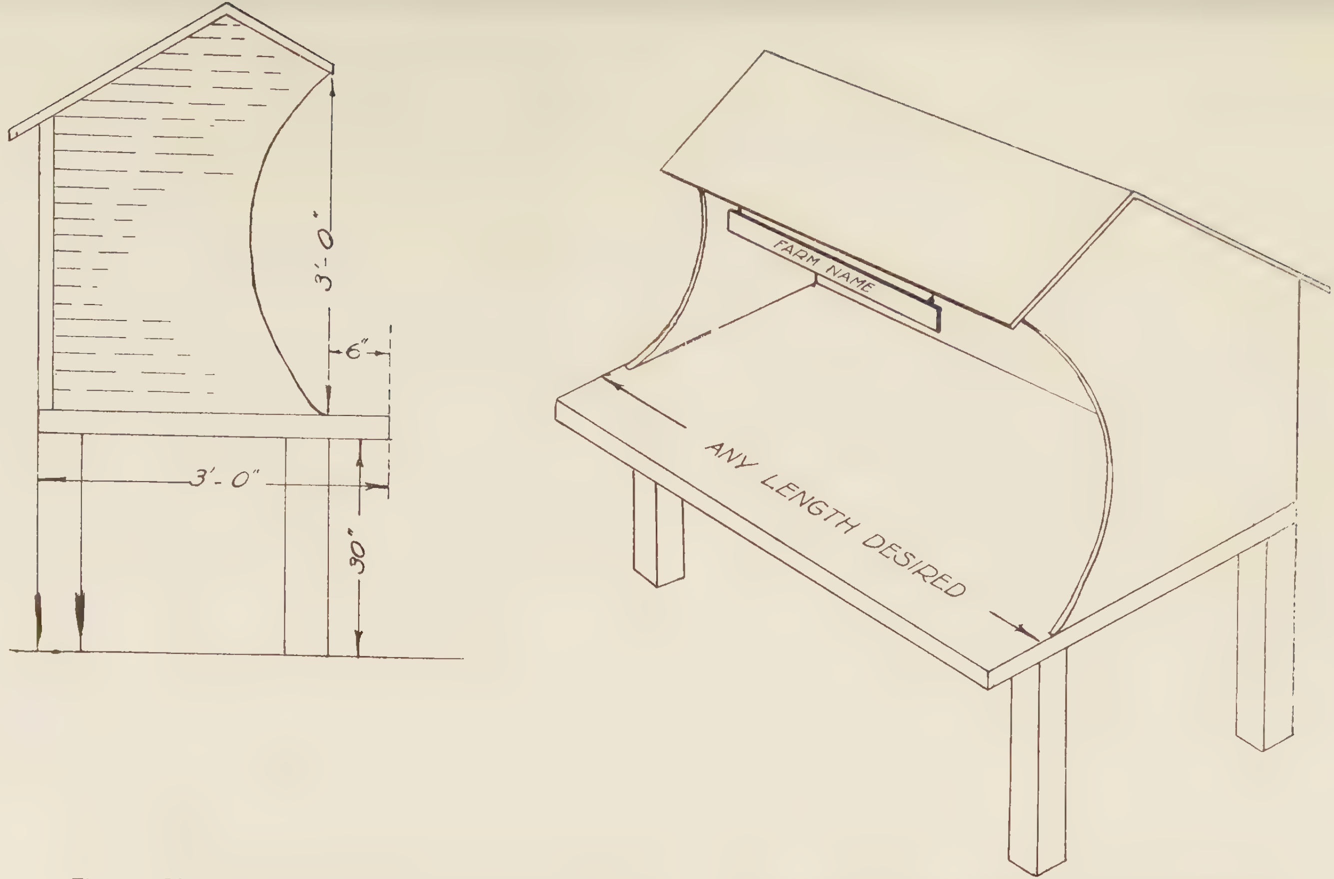


Fig. 27.—Plan for a suitable roadside loading platform for milk, designed for protection and to give an attractive appearance.

A Roadside Loading Platform

Most of the roadside platforms from which milk is collected by truck are crude and even ramshackle affairs. A neat roadside platform, well constructed, and furnishing the proper shade for the milk while awaiting collection, has a practical, advertising, and aesthetic value. The farm name may be attached to the platform if desired.

A loading platform of the type shown in Figure 27 would be a great improvement over the common type of platform in use, and its comparative value from the standpoint of appearance and advertising is apparent. The cost of making this improvement is nominal.

A Shipping Crate for Calves

In shipping a valuable animal possible damage will be overcome by use of a crate constructed to withstand the strains of handling and shipping. Many times crates are so carelessly put together that it makes handling on the road very difficult and increases the possibility of injury to the animal.

A crate such as is shown in Figure 28 may be constructed to fit the animal to be shipped, will stand considerable handling, and is as easily constructed as a crate which is merely "knocked together."

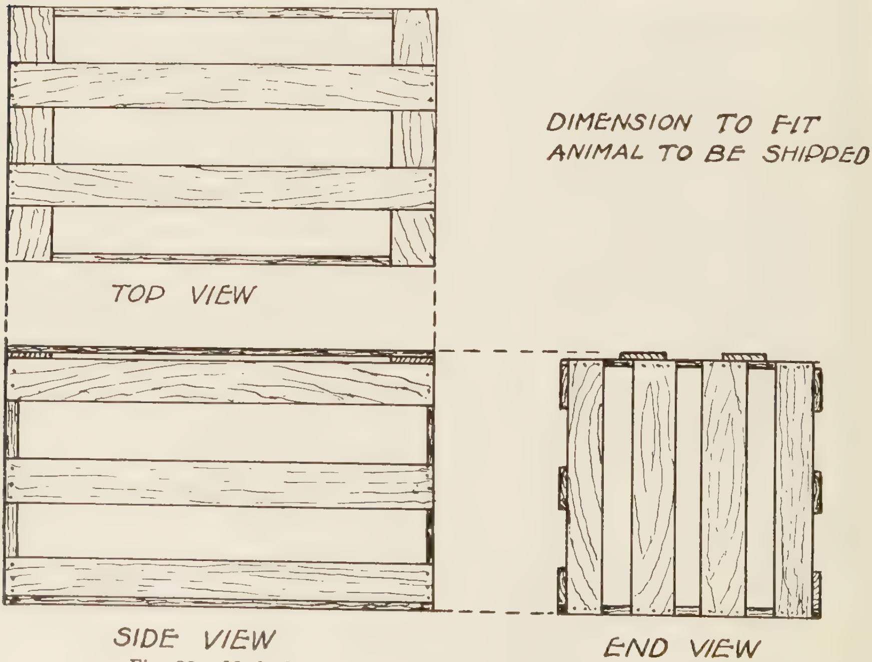


Fig. 28.—Method of constructing a satisfactory shipping crate.

ESTIMATING

Excavation

Multiply the length of the excavation by the width and depth in feet and divide by 27. This will give the dirt to be removed in terms of cubic yards.

Concrete

For foundations and floors the amounts of materials needed may be determined from Table 3.

TABLE 3.—Quantities of Materials Needed in Concrete Construction.*

Mixtures	Materials			Quantities from One-sack Batches		Quantities for 1 cu. yd. of Mixed Material		
	Cement in Sacks	Sand cu. ft.	Pebbles or Stone cu. ft.	Mortar	Concrete	Cement in Sacks	Sand cu. ft.	Pebbles or Stone cu. ft.
1:1½	1	1.5	.	1.75	...	15.5	23.2	....
1:2	1	2.0	.	2.1	...	12.8	25.6	....
1:3	1	3.0	.	2.8	...	9.6	28.8	....
1:1½:3	1	1.5	3	....	3.5	7.6	11.4	22.8
1:2:3	1	2.0	3	....	3.9	7.0	14.0	21.0
1:2:4	1	2.0	4	....	4.5	6.0	12.0	24.0
1:2½:4	1	2.5	4	....	4.8	5.6	14.0	22.4
1:2½:5	1	2.5	5	....	5.4	5.0	12.5	25.0
1:3:5	1	3.0	5	....	5.8	4.6	13.8	23.0
1:3:6	1	3.0	6	....	6.4	4.2	12.6	25.2

*Portland Cement Association.

Example: How much cement, sand, and pebbles will be required to build a feeding floor 30 by 24 feet, 5 inches thick?

Multiplying the area (30 by 24) by the thickness in feet ($\frac{5}{12}$ ft.) gives 300 cubic feet, and dividing this by 27 gives $11\frac{1}{9}$ cubic yards as the required volume of concrete. A one-course floor should be of 1:2:3 mixture. The table shows that each cubic yard of this mixture requires 7 sacks of cement, 14 cubic feet of sand, and 21 cubic feet of gravel or stone. Multiplying these quantities by the number of cubic yards required ($11\frac{1}{9}$) gives the quantities of material required (eliminating fractions) as 78 sacks of cement, 156 cubic feet of sand, and 233 cubic feet of pebbles or stone. As there are 4 sacks of cement in a barrel, and 27 cubic feet of sand or pebbles in a cubic yard, it will require a little less than 20 barrels of cement, 6 cubic yards of sand, and 9 cubic yards of pebbles or stone.

Sills, Joists, Studding, and Rafters

In figuring the quantity of materials needed for sills, determine the linear measurements of the sills and from their size determine the number of board feet needed. Do the same for all floor joists, studding, and plates. In figuring the studding no deduction need be made for any wall openings. The total length of the rafters and the number may be determined and figured as the other materials mentioned.

To determine the number of board-feet in a piece of timber multiply the width of the piece in inches by the thickness in inches by the length in feet and divide by 12. For example, a piece 2 inches thick, 12 inches wide, and 12 feet long contains 24 board feet, calculated as follows:

$$\frac{\text{Width } (12'') \times \text{Thickness } (2'') \times \text{Length } (12')}{12} = 24$$

Lumber commonly carried in stock comes in even lengths ranging between ten and twenty feet. Short lengths have a reduced sale value. Lumber for casings and trim is sold by the board-foot also, except moldings which are sold by the linear foot.

Flooring, Ceiling, Siding, Sheathing

In estimating the quantity of flooring needed, determine the number of square feet in the floor, including openings as though they were not present, and for three inch wide flooring add $\frac{1}{2}$ for waste and matching. For wider flooring add from $\frac{1}{4}$ to $\frac{1}{5}$ instead of $\frac{1}{2}$. Ceiling for the stable is estimated in the same way as flooring.

To determine the amount of siding needed, calculate the total wall surface in square feet and add $\frac{1}{2}$ if siding is laid four inches to the weather. If laid $4\frac{1}{2}$ inches or more, add from $\frac{1}{3}$ to $\frac{1}{4}$.

For common sheathing laid horizontally, figure the areas to be covered as though no opening existed, and add $\frac{1}{10}$ to the area to allow for waste. If the sheathing is laid diagonally, add $\frac{1}{6}$ to the total area.

For tight sheathing laid horizontally, add $\frac{1}{5}$ for 6-inch boards, $\frac{1}{7}$ for 8-inch boards, and $\frac{1}{9}$ for 10-inch boards. If laid diagonally, add $\frac{1}{4}$ for 6-inch boards, $\frac{1}{6}$ for 8-inch boards, and $\frac{1}{8}$ for 10-inch boards.

Windows and Doors

Windows are ordered by specifying the kind, as single sash or double sash, and by giving the number and size of the glass in each sash.

Doors are ordered in much the same way, by giving the size, thickness, and number of panels desired. The common thickness for doors is $1\frac{3}{4}$ inches, and they may be obtained in either A or B quality.

Roofing

When shingles are laid four inches to the weather, 1,000 shingles will cover 100 square feet. Roll roofing contains enough material in each roll to cover 100 square feet. In the case of asphalt shingles, laid four inches to the weather, four bunches will cover 100 square feet.

Circular 50

September, 1928

Crop Rotations for West Virginia

BY D. R. DODD, R. J. GARBER AND T. E. ODLAND

A profitable West Virginia farm on which rotation of crops is practiced.

Agricultural Experiment Station

College of Agriculture, West Virginia University

F. D. Fromme, Director, Morgantown

ROTATION REMINDERS

1.—The best farms in West Virginia have well-planned crop rotations.

2.—Crop rotation is only one of the several factors of good farm practice necessary for profitable crop production. It is, however, the first essential.

3.—Rotations increase farm profits in two ways: first through increased yield, and second through better farm organization.

4.—Due to the wide variation in types of farming, topography, climate, and crops grown in West Virginia, nearly every farm becomes a separate problem and requires individual consideration in determining the proper rotation. This accounts to a large extent for the many farms where definite rotations have not been adopted.

5.—There are five essentials in a good crop rotation. It should provide for:

(a) Crops adapted to the soil type, topography, and climate.

(b) Crops adapted to the type of farming.

(c) Crops from the four main groups: cultivated, legume, small grain, and sod crops.

(d) A sequence of crops conducive to high yields and economic production.

(e) The proper application of lime, manure, and fertilizer.

Crop Rotations for West Virginia

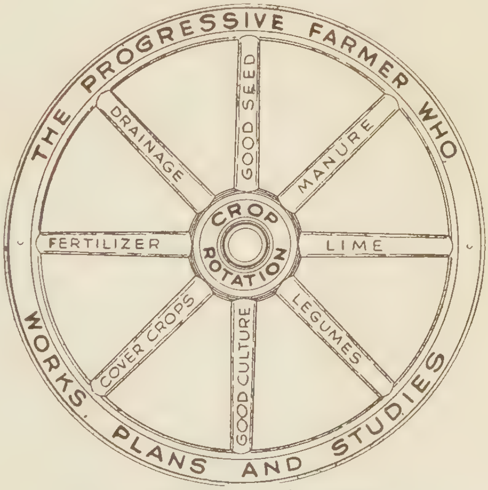
Crop Rotation Defined

A careful examination of the farm practices followed on the more profitable farms in West Virginia shows that the operators of these farms use a well-planned crop rotation. They have a regular order of carefully chosen crops which occur in the proper sequence and at regular intervals on the same land, during a period of years. For example, if the rotation is corn, soybeans, wheat, and clover, corn will occur on a certain field the first year and then every fourth year thereafter. Soybeans will occur the second and every fourth year thereafter; wheat the third and every fourth year thereafter; and clover the fourth year and every fourth year thereafter.

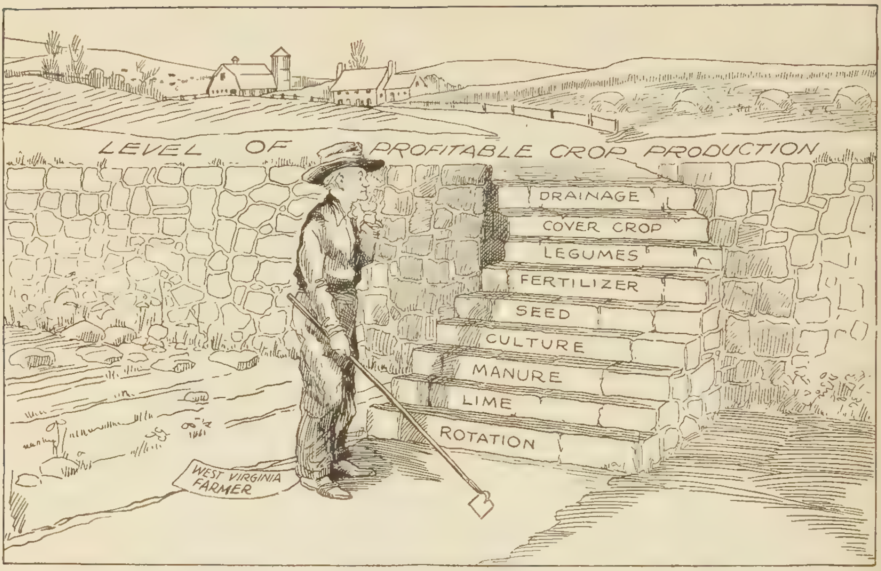
Relation of Rotation to Farm Practices

There is usually a close relation between crop rotation and maximum crop yields. High yields are, to a certain degree, dependent upon a well-planned crop rotation. This, however, is only one of the factors in successful crop production, and it should be accompanied by those other factors which together with crop rotation are known as good farm practices.

These combined practices may be likened to a wheel, of which crop rotation is the hub; other good farm practices the spokes fitting into the hub; and the farmer himself the rim and tire which bind all together. All are essential, and when combined form the wheel that will successfully carry the load of profitable crop production. Due to the inter-relation of these factors, a discussion of crop rotations, independent of the other factors, would be incomplete.



The wheel that will carry the load of profitable crop production.



Why not farm on the higher level?

INTERDEPENDENCE OF FACTORS

The interdependence of the factors of good farm practice is evidenced in the experiences of certain farmers in every county in the state. Practically every community has its outstanding examples of successful crop production by a few men who observe all these factors, and likewise has its outstanding examples of failures by some who neglect one or more of the factors. Lime and fertilizer may be profitable for one man but not for his neighbor with the same type of soil. The explanation lies in a difference in seed, cultural methods employed, crops grown, or other factors which have been disregarded. The failure comes about in spite of the liming and fertilizing, because other equally important farm practices have been neglected.

At the Missouri Agricultural Experiment Station, corn was grown continuously on the same land for thirty-one years. Where no lime, manure, or fertilizer was used, the yield the thirty-first year was 19.6 bushels per acre. On the adjoining plots, where manure was used, the yield was 39.1 bushels. On a third series of plots where manure was used in connection with a rotation of corn, oats, wheat, and clover, the yield was 60.1 bushels. Manure used in connection with a good crop rotation gave a yield of corn 21 bushels per acre greater than a like application of manure used in connection with continuous cropping.

At the same station, a similar experiment, except with wheat instead of corn, gave in the twenty-ninth year a yield of 10.9 bushels of wheat per acre where manuring and continuous cropping were practiced and 39.4 bushels where manuring and crop rotation were practiced.

From these yields obtained with manure and continuous cropping it might seem to the careless observer that it does not pay to use manure. Likewise in the case of similar experiments that gave like results when lime, fertilizer, or other factors of soil fertility were used with and without the rotation. The facts, however, are that while lime, manure, fertilizer, and rotation all have a tendency to increase crop yields, no one of them alone can long produce profitable crops.

RELATION OF ROTATION TO PRODUCTION

The remarkable ability of crop rotation to increase yields has been shown by numerous farm tests and station experiments. Typical of these is one conducted at the Ohio Experiment Station.[1] Corn, oats, and wheat were grown continuously on respective series of plots. On another series of plots, corn, oats, wheat, clover, and timothy were grown in a five-year rotation. On still another series, corn, wheat, and clover were grown in a three-year rotation.

The continuous cropping and the five-year rotation experiments were begun in 1894, and the three-year rotation in 1897. All were still in progress when this circular was published. The influence of the respective treatments for the five-year period, 1921-25, is shown in tabulated form in Table 1.

Two things of particular significance are brought out in Table 1. The first is that crop production without crop rotation was so low that it failed to pay the cost of production. The second is that, even with such a good rotation as

TABLE 1—Effect of Crop Rotation Upon Organic Matter, Nitrogen Content, and Crop Productivity of the Soil at Ohio Agricultural Experiment Station, Wooster, for the Five-Year Period, 1921-25.*

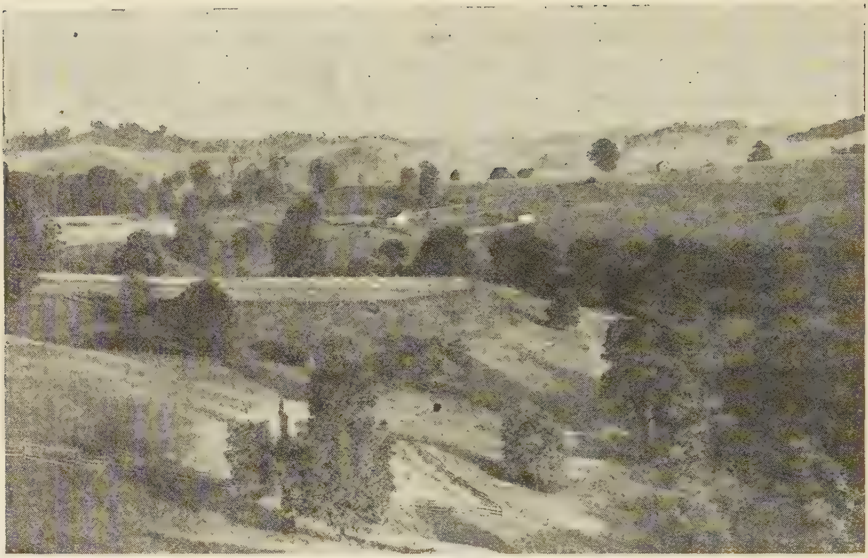
Cropping System	Amount of Organic Matter per Acre in Surface Soil, 1925‡ (lbs.)	Amount of Nitrogen per Acre in Surface Soil, 1925‡ (lbs.)	Average Yields of Crops					Average Annual Value†
			Corn (bu.)	Oats (bu.)	Wheat (bu.)	Clover (lbs.)	Timothy (lbs.)	
Continuous corn	12,520	820	6.7	......	......	....	....	$4.69
Continuous oats	21,720	1,300	......	15.3	......	....	....	6.12
Continuous wheat	21,830	1,320	......	......	7.4	....	....	11.10
Corn, oats, wheat clover, timothy	26,520	1,540	26.3	34.4	16.3	2,080	2,700	18.49
Corn, wheat, clover	29,550	1,760	40.0	......	17.9	3,030	....	25.86

*Compiled from unpublished data furnished by R. M. Salter, Chief in Agronomy.

†Values used in the calculations for this table were: corn, 70c per bushel; oats, 40c per bushel; wheat, $1.50 per bushel; and hay, $15.00 per ton.

‡The soil at the beginning of the experiments had approximately 36,830 pounds of organic matter and 2,240 pounds of nitrogen per acre.

[1] Ohio Agricultural Experiment Station, Bulletin 336, and unpublished data furnished by R. M. Salter, Chief in Agronomy.



As shown in this picture, the steeper areas of West Virginia farms should be in permanent pasture or in woods, while the more level areas should be fenced and farmed in a regular rotation.

corn, wheat, and clover, the nitrogen and organic matter contents of the soil were not maintained. In other words, while it is apparently useless to try to produce profitable crops without a rotation, rotation in itself is not enough. Every additional factor of good farm practice adopted not only makes an increase for itself but also increases the returns from every other such factor previously adopted.

For the five-year period, 1921 to 1925 inclusive, the average annual yield of corn in West Virginia was 32.9 bushels, wheat 12.7 bushels, oats 24 bushels, buckwheat 19.6 and hay 1.29 tons. Such yields as these return little or no profit and very frequently result in loss. The only possibility of raising them to a profitable level is through better farm practices centered about crop rotation.

RELATION OF ROTATION TO FARM ORGANIZATION

A good crop rotation plan greatly aids in the business organization of the farm. It provides for a more constant feed supply through the regular production of more or less uniform quantities of the various crops grown. Due to a more definite program, labor can be distributed and kept more efficiently employed. The annual needs for lime, fertilizer, seed, and other supplies become more stabilized, making it possible to purchase them further in advance and with less effort. It becomes much easier to keep a record of past soil treatment, and anticipate future requirements. In short, the whole farm business becomes more systematized and more profitable.

RELATION OF ROTATION TO PLANT NUTRIENTS AND AMENDMENTS

It has been pointed out that crop rotation alone will not maintain profitable crop production. Every pound of grain, hay, straw, livestock, or livestock products taken from the farm takes with it some of the soil fertility. The amounts of nitrogen, phosphorus, and potassium required per acre by eight common crops are shown in Table 2 (on page 8).

The systematic and regular application of barnyard manure or other form of organic matter together with lime, and fertilizer should be provided for in any good rotation plan. Barnyard manure is not well balanced, and when used alone, is not as profitable as when combined with superphosphate or other phosphatic fertilizer. Owing to the cheapness and abundance of manure in the past, it has been and still is grossly wasted. An application of 8 tons per acre once every four years, or the equivalent of this, will, under ordinary conditions, and with a good rotation, more than maintain the organic matter content of the soil. Many farmers have been unable to apply this amount, not because it is not produced, but because it is wasted. The average annual production of manure, exclusive of bedding, for the common farm animals per thousand pounds of live weight is about as follows:

Horse	9 tons	Steer	7 tons
Milk cow	13 tons	Hog	15 tons
Sheep	6 tons		

Calculations based on these amounts reveal that the farmer with 4 horses, 5 cows, 4 head of young stock, 20 sheep, and 5 hogs, should produce about 120

In the more level areas of West Virginia, such as the Greenbrier, Potomac, Shenandoah, and Ohio valleys, the crop rotation problem is not so difficult. This Jefferson county wheat field is on a farm where a three-year rotation of corn, wheat, and clover is practiced.

TABLE 2.—Amounts of Three Common Plant Nutrients Required per Acre by Certain Farm Crops on the Basis of the Assumed Yields. *(From Van Slyke.)*

Crops	Pounds of Elements Used per Acre		
	Nitrogen	Phosphorus	Potassium
100 bushels corn (including cobs)	98.0	17.8	23.7
3 tons stover	60.0	7.8	69.0
Total for corn crop	158.0	25.6	92.7
50 bushels oats	32.0	5.6	8.0
2 tons straw	24.0	3.6	42.0
Total for oats crop	56.0	9.2	50.0
25 bushels wheat	30.0	5.5	6.3
2 tons straw	20.0	2.8	20.0
Total for wheat crop	50.0	8.3	26.3
25 bushels soybeans	79.5	12.0	24.7
2 tons straw	36.0	5.2	24.8
Total for soybean crop	115.5	17.2	49.5
1 ton clover hay	42.0	4.4	33.0
1 ton timothy hay	25.0	4.8	16.6
1 ton alfalfa hay	49.0	4.4	34.8
100 bushels potatoes	19.6	3.9	23.5

tons of manure on his farm annually. A brief survey of the farms in West Virginia indicates that the average farmer of the state cannot account for one-half of this amount. This fact indicates that a large amount of manure must be lost due to poor care or improper handling. The best place to use manure is on a growing crop, preferably on sod land where it can be applied with greater ease and less cost than on tilled soil. The application may be made at any time, but due to the objection of coarse material in the hay, it is usually preferable to spread the manure just after the hay crop has been removed.

The application of manure should occur once in a three- or four-year rotation. In a five- or six-year rotation, the application may be made twice. Plowing should not be done immediately after the manure has been applied, since in such case the manure will drop freely to the bottom of the furrow and will not become well mixed with the soil. Due to extra cost and lack of time, the practice in vogue a few years ago of applying manure on plowed land has become uncommon.

Lime may be applied at almost any time. It has been customary in the past, however, to apply it on plowed land and work it in. This has generally been done before seeding wheat in the fall or planting corn in the spring. There is no objection to either practice, except that the extra work frequently delays seeding of the crop. It is also frequently difficult and expensive to get lime to the farm and on the field in the spring. In case the proper amount of lime is maintained in the soil by regular applications, the time at which it is applied in the rotation is of but little consequence.

The consideration of chief importance is that the use of lime be made a regular feature of the rotation until the lime requirement has been met, after which less frequent and lighter applications will be required. Lime may be applied to meadows in late summer, fall, winter, or spring, or on plowed land before the planting of any crop, with the exception of potatoes, watermelons,

and a few others. Due to the saving in labor and the possibility of better farm organization, the applications to sod land are becoming much more common. In brief, the time to lime is when there is time available to do the work.

Lime encourages scab growth on potatoes and for this reason applications in a potato rotation should be lighter and made soon after the potato crop is removed, or as long as possible in advance of the next crop of potatoes.

The kind of lime used makes little difference. The average application, until the lime requirement has been met, is about 2 tons of ground limestone, 1½ tons hydrated lime, or 1 ton of freshly burned lime. The amount to apply, however, should be determined by a study of crops grown, and by soil tests.

No rotation plan is complete until it makes provision for the regular and proper applications of fertilizers. The kind and amount to use will depend upon the crops included in the rotation, the amount of stable and green manure applied, and the type of soil. If an abundance of legumes is grown, or if manure is used freely, little or no nitrogen is needed. On grass crops, however, where manure is not freely applied, or on truck crops having a high cash value per acre, some nitrogen is advisable. Most legumes also respond to some potash, especially on the more sandy soils in southern West Virginia. Truck crops in all parts of the state also pay good returns on applications of potash.

All soils in West Virginia are deficient in phosphorous. This element is removed rapidly by grain crops and to a less extent through the sale of livestock from the farm. Moreover, the natural available supply of phosphorus is more limited than that of nitrogen or potassium. For these reasons, it is recommended that phosphorus be included in the fertilizing plan to accompany any system of crop rotation followed on West Virginia farms.

For the production of general field crops on the more fertile soils of the state, where an abundance of legumes and cover crops are provided for in the rotation, and where manure and lime are properly used, it is probable that but little additional profit can be obtained through the use of fertilizer other than phosphates, such as superphosphate. Where legumes are not frequently grown, or where applications of manure are light, fertilizers with analyses such as 2-14-4 or 4-12-4* may be expected to give better results than phosphates alone. The tendency in West Virginia is, doubtless, too much toward the exclusive use of superphosphate. This fertilizer is probably the most profitable one to use on farms with fertile soils that are rich in organic matter, but on the most farms of average soil fertility a complete fertilizer, as the 2-14-4, the 4-12-4, or the 4-10-6, will likely prove to be more profitable.

The amount of fertilizer to apply depends upon the crops grown and the other factors previously mentioned, but on general field crops an average of 300 or more pounds per acre per year will be found to give good results. It is customary to make the heaviest applications on crops to be sold for cash, since this enables one to get returns from his investment more quickly. Fertilizer is also commonly applied on small grain crops when they are followed by grass, clover, or other hay crops, seeded with the grain. In this case, the fertilizer is applied not only for the grain crop, but for the hay crop that follows as

*Percentages of nitrogen, phosphoric acid, and potash, respectively.

well. Applications may be omitted entirely from other crops in the rotation. Corn is a "gross" feeder, absorbing nutrients from coarse materials such as manure and sod.

ADOPT ROTATIONS ADAPTED TO CONDITIONS

With the foregoing general principles in mind, one may proceed with the formation of rotation plans suited to the needs of any specific farm. It is, undoubtedly, because of the wide variation in the requirements of different farms in West Virginia that the general adoption of rotation plans has not taken place more rapidly in the state. In many sections of the United States the types of soil, topography, climate, and types of farming are much alike and most farmers can follow one or another of a few standard rotations. This is not the case in West Virginia, and consequently many farmers must formulate new plans of their own. Good rotation plans are not common. There are examples of satisfactory ones, however, in every county.

Due to the topography of the state, the various types of farming, and the various sizes and locations of fields, the same rotation plan is not suited to all cases. The requirements of every farm must be considered separately. The rotation best adapted to the hill farmer frequently does not meet the requirements of the valley farmer. The requirements of the dairy farmer differ from those of the grain, truck, or livestock farmer.

Specific Principles to be Observed

The farmer who is really desirous of working out a good crop rotation need not despair, however, for there are certain underlying principles which are helpful in the selection or formation of any crop rotation plan. A careful study of these principles, a discussion of which follows, will be of value in planning a good rotation.

SELECT CROPS THAT ARE ADAPTED

The crops considered should first of all be adapted to the topography, climate, and soil type. Level land is well suited to the use of machinery and is not likely to be washed by heavy rains. For these reasons, corn, potatoes, and other crops requiring the extensive use of machinery are better adapted to the more level sections. Steeper lands, inclined to wash, should be kept in grass a greater part of the time. Buckwheat, potatoes, and oats are cool climate crops and are, therefore, suited to the higher lands of the state on the Alleghany plateau. Corn is a hot weather, moisture-loving crop, and is more at home on the lower lands of the state. Although corn is grown on practically every farm in the state, the most extensive corn areas are in the valleys of the Ohio, Potomac, and Shenandoah rivers. Oats, in addition to being a cool climate crop, is also an upland crop and is, therefore, better suited to the higher areas. Potatoes and buckwheat do best in light soils, while the small grains do better in heavier soils.

Casual observations of the crops of a community and the soil type on which they grow soon give one an insight into the best crops to select for a cropping plan. If attempts are made, however, to grow only certain crops on certain soils, the objectionable practice of continuous cropping is likely to result.

CHOOSE CROPS THAT ARE NEEDED

Ordinarily crops are grown either as feed for livestock or are marketed directly. Where help is available, and where topography and other factors permit, it is desirable to have some crops for each purpose. This makes one's income less subject to market changes in prices for individual products.

The kind and amount of livestock kept will have much to do with determining the crops to be grown. Mature beef cattle, as a rule, will use an average of about two tons of silage and one-half ton of hay per head during the winter. Dairy cows will, of course, use more. Hogs and horses are heavy users of corn. Seven sheep consume about as much feed as one cow. With a little figuring one should be able to determine the area of the different crops needed to supply feed for his livestock.

SELECT CROPS FROM DIFFERENT CLASSES

In order to obtain maximum crop yields and maintain proper soil improvement, a rotation should ordinarily include four classes of crops: cultivated, legume, small grain, and sod.

The purpose of the cultivated crop is to incorporate plant nutrients and organic matter in the soil, destroy weeds, loosen the soil, provide a more uniform soil, and increase bacterial and chemical action. The cultivated crop is commonly regarded as the first one in a rotation. The ground is plowed in preparation for it, and thus it is possible to incorporate a fresh supply of organic matter in the form of manure as well as the sod that is turned under.

The purpose of the legume crop is to aid in the maintenance of, or to increase, the nitrogen supply, and to penetrate the subsoil, thereby loosening it and providing a greater feeding area. Most legumes are not heavy feeders in the first two inches of surface soil. In order to maintain the nitrogen supply, a legume is needed under average conditions at least one year in three. With the exception of soybeans and cowpeas, legumes ordinarily can be established to best advantage for hay purposes when seeded in small grain, which serves as a nurse crop. Frequently, however, it is advisable to seed them alone in order to provide the needed number of legume crops in a rotation.

Small grain crops serve to smooth the land following the cultivated crops and provide good nurse crops for starting the clovers and grasses. Grain crops are frequently sold for cash.

The sod crops serve to prevent washing and leaching, and they feed freely from the surface soil.

A rotation made up of these different classes of crops keeps the supply of plant nutrients better balanced and draws upon larger areas of the soil.

ARRANGE CROPS IN PROPER SEQUENCE

After determining what crops are to be grown in the rotation, the question of proper sequence of these crops arises. The order of the crop in the rotation that will produce the greatest yields with the least work is the one that should be followed. It is a well known fact that certain crops do not grow well when preceded by certain other crops. For example, potatoes yield better after clover than after corn. Wheat yields better after corn than after buckwheat. The ways in which one crop may influence another crop following it are not entirely understood, but three possible ways are often suggested; namely, by

Where the area of level land is limited more intensive farming in a short rotation is preferable. Note the soybeans on this section of bottom land where a rotation of corn and soybeans is practiced.

production of toxic material, exhaustion of available food supply, and the harboring of insect pests and plant diseases.

There is evidence that certain materials injurious to plant growth are developed in the soil either as exudates from the roots or as products of decomposition of the crop residue. Such injurious materials produce a toxic effect which is thought to be largely responsible for the inability to maintain good yields under continuous cropping, even when manure is added.

Exhaustion of the available food supply occurs chiefly where two crops in succession have similar root systems and feeding habits. Practically all legumes have deep roots, feed freely, and draw rather heavily on the potash supply. They not only absorb largely the same nutrients, but draw them from the deeper portions of the soil. In a like manner, the small grains and grasses with fibrous surface roots have much the same type of root system and similar feeding habits. They draw chiefly from the surface soil. It is evident, therefore, that if legume and grass crops were alternated, the available plant nutrients in both surface and subsoil would be more efficiently utilized and a better growth of the crops in each group would result. The nitrogen supply may even be increased because of the legumes.

A third way in which certain crops may retard the yield of others following is through the propagation of insect pests and plant diseases. Good illustrations of the harboring of insect pests and plant diseases are found in the wintering of the European corn borer, corn root rot, and smut. All of these may live over in the old corn stalks or other materials and attack the next crop of corn. One of the corn root rot organisms also attacks wheat, causing scab. Where a disease common to two crops is present it is not desirable that one crop

should follow the other and ordinarily the same crop should not be planted twice in succession on the same land.

It has been mentioned that a cultivated crop in the rotation is necessary in order to incorporate organic matter, loosen the soil, and destroy weeds and insects. Thorough cultivation ordinarily is not necessary more than once in every three years. Consequently, two crops, both of which require plowing, should not ordinarily follow each other. For example, wheat may follow corn witnout plowing, grass and clover may be seeded in the wheat, and this in turn may be cut for hay one or more years. This gives three or more crops from a single plowing, and is desirable in case wheat scab is not present. If the land is adapted to alfalfa, this crop may be seeded in the grain instead of grass and clover, and several more crops thus obtained from a single plowing. It is never advisable to plow for a crop that can be produced without plowing unless the soil is in need of plowing for other reasons. The old practice of plowing sod for wheat has practically gone out of existence, largely for this reason.

SOME STANDARD CROP ROTATIONS

Many good rotation plans have already been formulated and tried out by West Virginia farmers. A number of these are presented in the following pages along with others which have been modified or formulated as a basis for selection and rearrangement.

From a soil fertility point of view, probably three- or four-year rotations are best, but the length of the rotation is commonly determined by the amount of land available and the portion of it which can be handled in cultivated crops in any one year, the size and number of fields, the topography of the land, and the type of farming desired.

Two-Year Rotations

There are a number of farms in West Virginia with limited areas adapted to the production of some much needed crop. Under such circumstances a very short rotation is desirable. The four two-year rotations outlined in Table 3 are suited to these conditions.

A potato field on an Ohio valley farm where a rotation of potatoes and soybeans is followed. Rye is used as a cover crop and the soybeans as a green manure crop.

Rotation No. I, as outlined in Table 3, is adapted to the producer of potatoes who can get the crop dug and marketed early. Such conditions are to be found on limited areas operated by the truck-crop men near the larger towns and cities. The sweet clover crop may be used for hay and pasture or turned under as a green manure crop. If it is found necessary to reduce the application of manure, a 4-10-6 fertilizer should be used instead of the superphosphate. The 0-14-6 is advisable on the more sandy soils even when the full application of manure is made.

TABLE 3.—Four Suggestive Two-Year Rotations with Crop Management Plans.

No.	Year	Crop	Cover Crop	Manure	Fertilizer	Lime*
I	1st	Early potatoes	Sweet clover; seeded at the rate of 15 pounds per acre when potatoes are dug	None	800 - 1200 pounds superphosphate, 0-14-6 or 4-10-6 fertilizer, depending upon type of soil and amount of clover and manure plowed under	As needed every other rotation following potatoes
	2nd	Sweet clover hay	Residue of sweet clover	10 tons on sod, after mowing	None	None
II	1st	Corn	Rye and vetch; seeded at the rate of 1 bushel rye and 15 to 20 pounds vetch per acre at last working	None	400 pounds superphosphate or 2-14-4	None
	2nd	Soybeans	Rye alone; 6 pecks per acre	6 tons on rye before plowing for corn	200 pounds superphosphate	As needed every third rotation
III	1st	Potatoes	Rye and vetch; seeded at the rate of 1 bushel rye and 15 to 20 pounds vetch per acre when potatoes are dug	None	800 - 1200 pounds superphosphate, 0-14-6 or 4-10-6 fertilizer, depending upon type of soil and amount of clover and manure plowed under	As needed every other rotation after potato digging
	2nd	Rye and vetch hay	Soybeans seeded in July	10 tons on rye and vetch or soybean stubble	None	None
IV	1st	Corn	Red clover and timothy; seeded at last working	None	400 pounds superphosphate or 2-14-4	None
	2nd	Red clover and timothy hay	Timothy	6 tons on sod after mowing	None or 200 pounds 6-8-6	As needed every third rotation

*All lime applications are stated in terms of ground limestone. If hydrated lime is used, 1480 pounds may take the place of a ton, or if freshly burned lime is used, 1120 pounds are equivalent to a ton of ground limestone.

Corn

Soybeans

A two-year rotation adapted to farms having limited areas of crop land and demanding maximum production. A cover crop should be seeded after both corn and soybeans.

Rotation No. II, of the two-year group, is suited to the dairyman or livestock man who has a piece of ground near his silo on which he wants corn as frequently as possible. Soybeans make excellent hay for dairy cows. In case of reduced applications of green or barnyard manure, a 2-14-4 or a 4-12-4 fertilizer should be substituted for the superphosphate.

Rotation No. III is a two-year plan well suited to the man who has a limited area exceptionally well adapted to potatoes, and who, therefore, desires to grow potatoes as often as advisable.

A fourth two-year plan, outlined in Rotation No. IV, is being used in Lewis county and elsewhere in the state where frequent crops of corn are desired, and where it is desirable to get the ground back in sod as soon as possible. The rotation is not popular, however, due to the frequent failures of red clover when seeded in corn. This rotation may be extended to three years by allowing the grass and clover to remain another year.

Three-Year Rotations

For farmers who desire rotations extending over a three-year period one of the three rotations given in Table 4 or a modification of one of these is recommended.

Of the three-year series, Rotation No. I has a wide adaptation. It is in use in practically every county of the state. By changing the seed for the hay crop it may be made to serve the farmer who generally prefers a mixed hay or

TABLE 4.—Three Suggestive Three-Year Rotations With Crop Management Plans.

No.	Year	Crop	Cover Crop	Manure	Fertilizer	Lime
I	1st	Corn	Wheat for grain, or rye and vetch, if oats follows	None	400 pounds superphosphate	None
	2nd	Wheat or oats	Clover for hay either sweet or red with or without timothy	None	400 pounds superphosphate or 2-14-4	As needed every other rotation here or on sod after grain crop
	3rd	Clover	Second crop clover and grass	8 tons on meadow after mowing	None	None
II	1st	Potatoes	Rye and vetch; seeded at the rate of 1 bushel rye and 15 to 20 pounds vetch per acre when potatoes are dug, if followed by oats; otherwise wheat for grain	None	1000 - 1200 pounds superphosphate, 0-14-6 or 4-10-6 fertilizer, depending upon type of soil, manure applied, and clover plowed under	None
	2nd	Oats or wheat	Clover for hay, either sweet or red, with or without timothy	None	None	As needed every other rotation
	3rd	Clover	Second crop clover and grass	10-20 tons on clover sod after mowing	None	None
III	1st	Red clover and buckwheat	Clover seeded in buckwheat	10-20 tons after harvest of buckwheat	200 pounds superphosphate	None
	2nd	Potatoes	Wheat for grain	None	1000 - 1200 pounds superphosphate, 0-14-6 or 4-10-6 fertilizer, depending upon type of soil, manure applied, and clover plowed under	None
	3rd	Wheat	Clover for hay	None	None	As needed other rotation before seeding wheat

An excellent timothy crop on a Harrison county farm in the third year of a corn, clover, timothy rotation. This field gave a yield of more than three tons per acre.

the dairyman who wants a legume hay. It provides corn for grain or silage, and grain for feed or sale. The objections most commonly made to it are that corn land is generally not very smooth and corn stubble is present, both of which are objectionable in the hay crop. Further objection lies in the fact that

A field of alfalfa on a Jefferson county farm. This crop is best grown in long rotations, or where it may stand for several years.

where corn is shocked and followed by wheat, the shock rows cannot be seeded to grass and weedy patches result in the following hay crop. If these objections can be overlooked, the rotation is not easily improved upon in the three-year class.

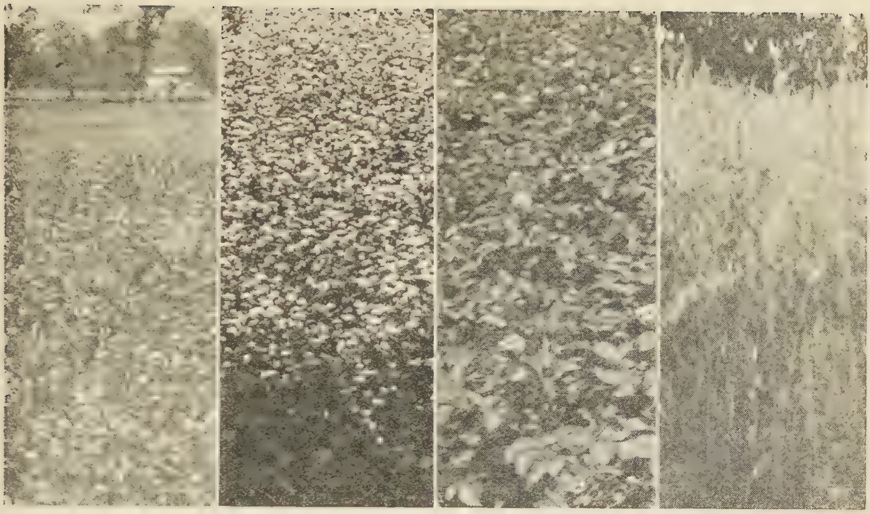
Rotation No. II, of the three-year group, is a modification of No. 1 which provides for potatoes. This rotation is now most in use in the potato territory in the Alleghany plateau counties and along the Ohio river. The objections of uneven land and shock rows do not apply here. On the more sandy soils of the state where full applications of manure are made 0-14-6 should replace superphosphate. On any type of soil where the application of manure is reduced, the 4-10-6 is preferable.

A three-year plan that includes four crops is that of rotation No. III in Table 4. This rotation is particularly adapted to the Alleghany plateau where the climate is well suited to the growing of potatoes and buckwheat. The rotation is a good one from every point of view. The first year clover is cut for hay and the land is plowed at once for buckwheat; thus two crops are harvested the first year. The plowing and the buckwheat aid in breaking down the sod and getting the soil in good physical condition for potatoes. Clover may also be seeded in the buckwheat to serve as a cover crop. The tender young clover plants decay readily when turned under for potatoes. Oats or rye may be substituted for wheat.

These three-year rotations may be lengthened to four or five years by allowing the grass to remain longer before breaking the sod, but such practice is objectionable except on steep land, in which case, the seed mixture should include red top. Top dressing the grass will also be necessary.

Potatoes *Wheat* *Clover*

These crops make a desirable three-year rotation for the potato-growing sections of West Virginia. In other sections where a three-year rotation is followed, it usually consists of corn, wheat, and clover. Frequently other grains are used in place of wheat.



Clover *Buckwheat* *Potatoes* *Oats*

A three-year rotation adapted to Alleghany plateau region including four crops in three years. Buckwheat follows clover the first year. Wheat or rye may be substituted for the oats.

Four-Year Rotations

On some West Virginia farms rotations requiring more than three years are desirable. For these farms one of the three four-year plans outlined in Table 5 or a modification of it is recommended.

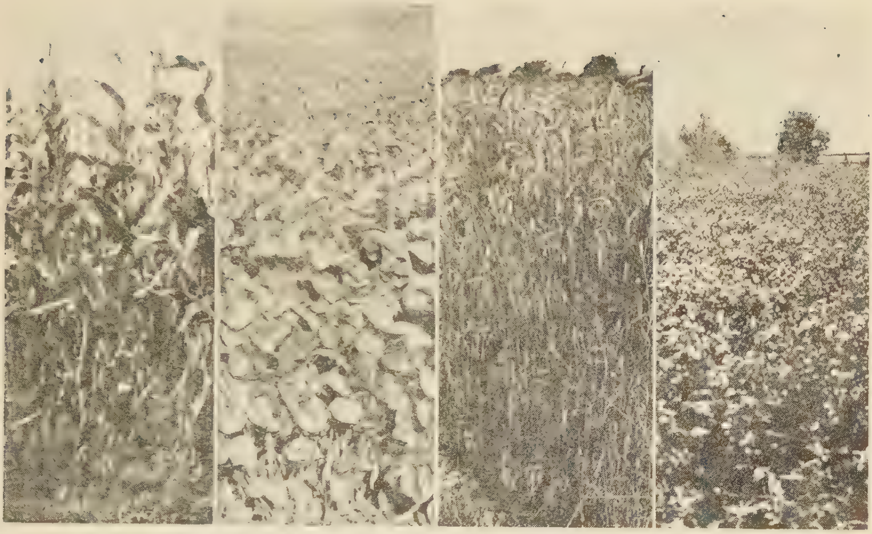
Rotation No. I in the four-year series has two or possibly three advantages over No. I of the three-year group. It has an extra crop which may be sold. It leaves the land smoother and cleaner for hay, and in case soybeans are used the second year, it has an extra legume crop. For the dairyman who has land enough to handle a four-year rotation, this one, with soybeans the second year and sweet clover the fourth, is not easily surpassed. Other cultivated crops might be substituted for corn. This rotation has one disadvantage, however, when compared with No. I of the three-year group, in that two plowings are required in four years instead of one in three.

The four-year plan given in Rotation No. II is a modification of No. I, which provides for potatoes or other truck crops the first year. These four-year rotations, in one form or another, are becoming more popular in many sections of the state, especially in the Eastern Panhandle, and along the Ohio river where they are replacing an old five-year rotation of corn, wheat (two years), clover, and timothy.

In the five-year rotation referred to, the three crops the first three years are all subject to corn root rot or wheat scab, and there are not sufficient legume crops to keep up the nitrogen supply. Where wheat scab is not present, and where land is level and easy to get over with machinery, this five-year plan has been giving relatively satisfactory results.

TABLE 5.—Three Suggestive Four-Year Rotations with Crop Management Plans.

No.	Year	Crop	Cover Crop	Manure	Fertilizer	Lime
I	1st	Corn	Rye and vetch, seeded in corn at the rate of 1 bushel rye and 15 to 20 pounds vetch per acre	None	400 pounds superphosphate	None
	2nd	Soybeans	Wheat	None	200 pounds superphosphate	None
	3rd	Wheat	Red clover, sweet clover, or clover and timothy for hay	None	400 pounds superphosphate or 2-14-4	As needed every other rotation here or on sod after grain crop
	4th	Clover	Same as for third year	12 tons on meadow before corn	None	(See above)
II	1st	Potatoes	Rye and vetch or sweet clover	None	1200-1500 pounds superphosphate, 0-14-6 or 4-10-6, depending upon type of soil, manure and clover crop turned under	None
	2nd	Soybeans,	Wheat	None	None	As needed every other rotation
	3rd	Wheat	Red clover, sweet clover, or clover and timothy for hay	None	300 pounds superphosphate or 2-14-4	None
	4th	Clover	Same as for third year	10-20 tons on clover sod before plowing	None	None
III	1st	Potatoes	Rye and vetch or sweet clover	None	1200 - 1500 pounds superhposphate, 0-14-6 or 4-10-6 depending upon type or soil, manure and clover crop turned under	None As needed every other rotation after digging potatoes or before planting corn
	2nd	Corn	Wheat	None	None	(See above)
	3rd	Wheat	Red clover, sweet clover, or clover and grass for hay	None	300 pounds superphosphate or 2-14-4	None
	4th	Clover	Clover and grass	10-20 tons on sod after mowing	None	None



Corn *Soybeans* *Wheat* *Clover*

A four-year rotation suited to rapid soil building and well adapted to dairy farming. A cover crop of rye and vetch should follow the corn.

The third of the four-year rotations given in Table 5 is used by some of the leading farmers in West Virginia and is giving good results both from the standpoint of crop yields and the maintenance of soil fertility. On the more sandy soils of the state and where full applications of manure are made in both rotations, No. 2 and No. 3, of this group the potato fertilizer should be changed from superphosphate to 0-14-6. On any type of soil where the application of manure is reduced the 4-10-6 should be substituted.

Five-Year Rotations

For farms on which a rotation longer than those previously suggested is found to be desirable, two five-year plans are given in Table 6. These five-year crop rotation plans meet the requirements of good farm management principles, and are recommended as being suited to conditions in West Virginia where long rotation plans are preferable to short ones.

The first of the five-year rotations in Table 6 is suggested as a substitute for the old five-year rotation of corn, wheat (two years), clover, and timothy, previously referred to. It has the two distinct advantages over the old one of separating the corn and wheat crops and of adding an extra legume. It is well adapted to the regions where small grains, grass, and corn thrive, particularly in the Ohio, Potomac, and Shenandoah valleys.

The second of these five-year rotations is adapted to the same regions as the first and also to the Northern Panhandle of the state. The rotation may be extended to six or seven years. In event it is so continued the fertilizer treatment for the alfalfa should be repeated every other year.

TABLE 6.—Two Suggested Five-Year Rotations with Crop Management Plans.

No.	Year	Crop	Cover Crop	Manure	Fertilizer	Lime
I	1st	Corn	Rye and vetch; seeded at the rate of 1 bushel rye and 15-20 pounds vetch per acre	None	400 pounds superphosphate or 2-14-4	None
	2nd	Soybeans	Wheat for grain	None	200 pounds superphosphate	None
	3rd	Wheat	Clover and timothy for hay	None	400 pounds superphosphate or 2-14-4	As needed each rotation here or on sod after grain
	4th	Clover	Second crop clover and grass	None	None	None
	5th	Timothy	Timothy sod	12 tons on meadow after mowing	300 pounds 6-8-6	(See above)
II	1st	Corn	Wheat for grain or rye and vetch for green manure	None	400 pounds superphosphate	None
	2nd	Wheat or oats	Alfalfa	None	400 pounds 2-14-4	As needed here or on alfalfa sod
	3rd	Alfalfa	Alfalfa	None	None	None
	4th	Alfalfa	Alfalfa	None	300 pounds superphosphate or 0-14-6	(See above)
	5th	Alfalfa	Alfalfa	12-15 tons on sod during fall and winter before corn	None	None

Another long-period rotation, which is more a necessity than a deliberate plan, is in use on much of the steeper lands of the state. Plowing frequently results in severe erosion on such slopes and, therefore, the land is broken only once in five or ten years, planted to corn one or two years, and followed by small grain and grass. Under such conditions the land should be manured heavily before plowing and fertilized heavily with a 2-14-4 fertilizer when the land is reseeded to grain and grass. Top dressing of a mixture of 200 pounds sulphate of ammonia, and 400 pounds superphosphate applied at the rate of 400 pounds

per acre about every other year thereafter, will hold a good sod of timothy for seven or eight years, other conditions being favorable. On sandy soils the further addition of 100 pounds of muriate of potash to this mixture is recommended. This is the equivalent of a 6-9-7 ready mixed fertilizer. If a mixed fertilizer is used, a 6-8-6 is recommended.

PASTURE

In the rotations herein discussed, no provision has been made for temporary pasture. Any of the rotations containing grass may be pastured a year or more before plowing again for the cultivated crop. In such cases the manure should usually be applied on the pasture the last year before plowing. If two applications are desired, one may be made during the last year of pasture and the other on the new meadow. Since pasturing often lengthens the rotation and reduces the frequency with which legumes occur, increased applications of fertilizer such as 2-14-4 and 4-12-4 may be expected to give more satisfactory results under such conditions. It is usually better, however, to keep crop land and pasture separate.

An excellent crop of clover on a Jackson county farm. This field has been made to produce three times the yield of twelve years ago through the use of rotation, manure, lime, and superphosphate.

RCULAR 51 AUGUST, 19

Better Seed Corn

GROWING-SELECTING-STORING-TESTING

High Points on Seed Corn

Choose a variety of corn that you know is adapted to your location. If you have a neighbor who has high-yielding corn, it is safer to obtain seed from him than to obtain it a long way from home.

Select seed corn in the field before a killing frost

Select mature ears which are borne on vigorous stalks in competition with other stalks. If the corn was planted in hills, select ears from 2- or 3-stalk hills surrounded by other 2- or 3-stalk hills.

Never select ears from stalks which show symptoms of disease. Some of the indications of a diseased stalk are: Smut boils, broken shanks, a broken or lodged stalk, a weak growth, and a premature ripening.

It is advisable to select ears that are borne at a convenient height on the stalk and that have their tips covered by the husk. Avoid selecting ears that have tips exposed.

If a plant matures normally, the husk on the ear should dry while the plant is still green. It is at this stage that the ears should be selected.

A diseased condition is usually associated with rough starchy ears, therefore, such ears should be avoided.

Select at least twice as many ears as will be needed for seed.

Dry all ears selected in a well-ventilated room. It is important to have each ear stored in such a way as to allow a free circulation of air around it.

Late in the winter or early in the spring, test each ear for germination and the presence of disease and discard any ear which shows weak germination or symptoms of disease.

Better Seed Corn

Growing, Selecting, Storing, Testing

By R. J. GARBER and M. M. HOOVER

CORN IS THE MOST IMPORTANT and the most widely cultivated field crop in West Virginia and for this reason deserves particular consideration. Frequently too little attention is given to seed. No matter how well the crop may be cultivated and fertilized, if the seed is poor the yields will be unsatisfactory.

Often additional investment in high quality seed will return a greater dividend than investment in any other item in connection with crop production. Two fields of approximately equal productivity may be given the same cultural and fertilizer treatments and yet there may be a marked difference in yield owing to the difference in the seed used.

With a crop like corn for which there is a relatively small number of seeds planted per acre the use of a few poor seed ears may lower the yield considerably.

IT IS NOT ENOUGH merely to know that we should follow certain practices and the mere mechanical routine of how to perform the operations in question. If we are to do our work intelligently, we must know the reason for doing things a certain way and why more satisfactory results will be obtained by this procedure than by some other.

In preparing this circular these facts have been kept in mind, and an attempt has been made to explain certain characteristics of corn which make certain practices in growing it, with a view to obtaining seed that will be better than the original seed that we started with, essential.

The first part of this circular, therefore, explains the reasons for the practices that are recommended in the latter part with the hope that this information will make the production of better seed corn on West Virginia farms not only easier but more fascinating and interesting to the grower.

Fig. 1.—A field of corn in which self-pollinations by hand have been made. A large number of bags which have been placed over tassels and a few bags which have been placed over ears may be seen.

Cross-Fertilization

In order to understand better some of the problems in obtaining desirable seed corn one should know something of the nature of reproduction in this plant. Corn is known as a cross-fertilized plant, that is, there are two different plants concerned in the production of each seed on the ear. The individual seed rather than the ear should be looked on as the unit. All the seeds borne on any particular ear have but one female parent but each seed may have a different male parent.

A normal vigorous corn plant may produce as many as 2,000-000 pollen grains in the tassel and 500 to 1000 ovules or eggs on the young ear. The ovules are enclosed in tiny sac-like structures on the cob and attached to each of these sac-like structures is a long hair-like appendage called a silk. When the ear is ready to receive the pollen (male element) the silk is extended beyond the husk. If a pollen grain falls on a silk it germinates and grows down along or through the silk until it reaches the tiny sac (female element). Here part of the contents of the pollen grain and of the tiny sac unite (the process being known as fertilization) and from this union a seed develops. Each seed on an ear of corn is produced in this manner, or by a similar union of male and female elements.

From the nature of reproduction in corn it is easily seen that by selecting seed ears from standing stalks in the field one may

ascertain the characteristics of the female parent stalks on which the ears are borne but not of the male parent stalks, from which the pollen was supplied. It is known from the studies of inheritance in corn that the male has just as much influence as the female in determining the characteristics of the progeny. It is possible to exclude natural cross-pollination and to make pollinations by hand and thus control the parentage of any particular ear, but this method is far too uncertain and expensive for the farmer. By selecting ears in the field one may obtain a good idea of the female parents and since one-half of the inheritance of the seed on any particular ear comes from the plant on which it is borne, it is certainly worth while to give some attention to this maternal plant. The only place this can be done is in the field.

Effect of Inbreeding

At the West Virginia and other agricultural experiment stations rather extensive projects in breeding corn are under way. An important feature of this work is the isolation of strains which breed more or less true. These strains are established by self-pollination—the most intensive kind of inbreeding known. When the ear has begun to "shoot," but before the silk appears, it is covered with a glassine paper bag and a few days later a manila bag is placed over the tassel. When the silk appears the pollen which has collected in the tassel bag is applied to it, after which a bag is again placed over the young ear and allowed to remain until harvest. By this kind of artificial self-pollination a great many different "selfed" strains of corn may be isolated from the same variety. After six or seven self-pollinations the individuals of any particular strain are remarkably like one another but the strains differ strikingly. It is possible, in fact, to isolate strains

Fig. 2.—Self-pollinating corn by hand.

Fig. 3.—Relatively pure strains of selfed corn which have been isolated by self-pollination. Note the difference between strains and the marked uniformity within any one strain. The cover crop which may be seen in the photograph consists of rye and hairy vetch seeded at the last cultivation of the corn.

from any one variety which differ more from one another than do any two ordinary varieties of corn (See Figure 3).

Such true breeding strains are generally low yielders, but a great difference is found between strains in regard to this characteristic. Some strains are lost because they fail to produce seed at all, some are low yielders, others medium and still others relatively high yielders but in no case has a selfed strain been isolated which produces much more than one-half the yield of ordinary field corn. It has been stated that the individuals of any one "selfed" strain resemble one another very closely. This is true in every detail of the plant and ear characters. *These facts show that self-pollination leads to uniformity of ear and of plant characteristics and reduces yields.*

A certain amount of uniformity in the ears of ordinary field corn may be attained by selecting ears for seed which conform very closely to some one type but, since uniformity is associated with lower yields, this practice seems questionable.

When two relatively pure self-pollinated strains are crossed the first generation progeny frequently yields more than the original commercial variety from which the strains are isolated. A

first generation cross between two varieties usually yields more than the average yield of the two varieties and sometimes yields more than the higher yielding parent. *These facts show that high yield in corn is associated with the crossed condition* (See Figure 4).

From the standpoint of the practical farmer who is interested primarily in high yield, any system of seed selection which tends to bring about inbreeding may be objectionable. This does not mean that it is necessary to grow a mixture of varieties in order to obtain maximum yields. In selecting seed, a safe plan is to pay particular attention to yield and disregard, very largely, type of ear.

In addition to reducing yield, inbreeding shows something of the hereditary qualities of ordinary commeccial corn. Just as the chemist may analyze a compound and find out what it contains, so the plant breeder may inbreed a commercial variety of corn and find out what it contains. It has been pointed out that the inbred strains differ strikingly with regard to yielding ability, although none has been isolated as yet which yields as high as an ordinary variety. The inbred strains differ strikingly also with respect to

Fig. 4.—Two self-fertilized strains of corn and a first generation cross between them. The tall row in the middle is the first generation cross and the short row growing on the right and the one on the left are the parents.

Fig. 5.—Two ears produced by a strain of self-fertilized corn. Note particularly the ear at the right of which approximately one-fourth of the seeds are defective. If these defective seeds are planted they will produce small stunted plants.

such characteristics as height of plant, width of leaves, coloring of stalk and leaves, size, shape and color of seed and cob, rooting habits, resistance to disease, and tendency to produce defective plants. These differences between inbred strains arise because of hereditary differences between the strains.

A few examples may bring out more clearly what is meant by hereditary difference in inbred strains. If one were to go into an ordinary corn field and self-pollinate 100 ears and the next year plant each of these 100 ears in separate rows, some interesting observations might be made. A few of the 100 rows would show approximately three green seedlings to one white, a few would show three green seedlings to one yellow, and still others would show other kinds of defective young plants. Some of the 100 rows would of course show nothing but normal green plants. Here, then, is evidence of the marked hereditary differences that exist in 100 self-pollinated ears of commercial corn.

In 1920 the artificial self-pollination of corn was begun at the West Virginia Agricultural Experiment Station. There are now something like 200 inbred strains established, some of which have been self-pollinated for eight successive generations. A few years ago one of these strains produced some self-pollinated ears, one-fourth of whose seeds were defective (See Figure 5). The defective seeds and the normal seeds from the same ear were planted in separate rows. The difference in the plants coming from these two kinds of seed may be seen in Figure 6.

One of the corn diseases which causes considerable damage in West Virginia is smut. The inbred strains of corn on the Agronomy Farm at Morgantown are grown under conditions which encourage the development of corn smut. Some of the inbred

strains are very susceptible to this disease and others are highly resistant. The two inbred strains shown in Figure 7 were both isolated from the Leaming variety. One of the strains is very susceptible to smut as is evident from the large smut boils near the base of the plants, whereas, the other strain does not show any evidence of the disease.

From these observations and many others of a similar nature it is concluded that the ordinary variety of corn is made up of a mixture of a great many characteristics, some desirable and others not. It would seem then that a logical method of improving corn would be: (1) to practice inbreeding, (2) to eliminate the more undesirable strains, and (3) to hybridize the more desirable ones, thus producing a new variety. In fact this is essentially the method being followed at most of the agricultural experiment stations where corn breeding is carried on. This method, however, is much too expensive for the practical farmer.

The inbreeding of corn shows in a striking manner that the ordinary corn field contains many different kinds of corn plants and for this reason, it appears that seed ears for commercial planting should be selected in the field, where attention may be given not only to the ear but, what is perhaps more important, to the stalk which produces the ear. The only place where this can be done is in the field.

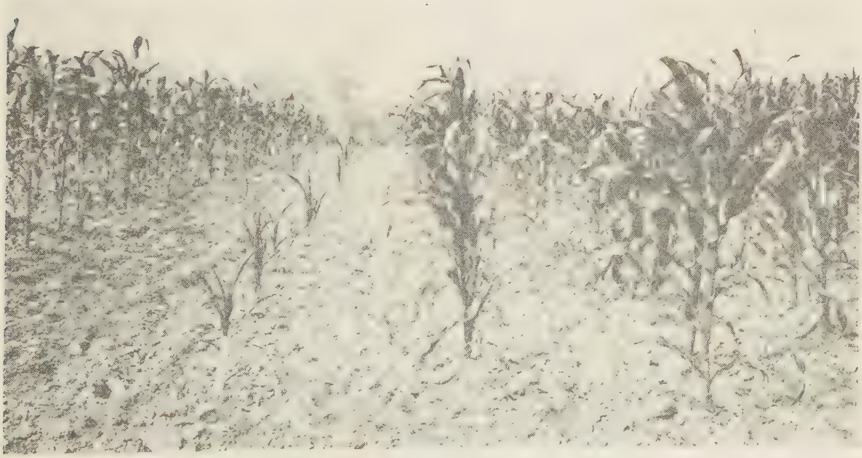


Fig. 6.—The corn plants in the rows at the left came from defective seed and those in the two rows at the right came from normal seed. Note the poor stand and inferior plants produced by the defective seed.

Fig. 7.—Two strains of corn which have been isolated from the Leaming variety by self-pollination. Note the difference in smut infection. The strain at the right has large smut boils near the base of the plants, whereas the strain at the left is free from smut.

Buy Locally Grown Seed

Sometimes a farmer is forced to purchase his seed corn from a neighbor or a seed firm. It is very important that such purchased seed be adapted to the conditions under which it is to be grown.

A few years ago the Agronomy Department conducted varietal experiments at several places in the state and compared local varieties with varieties that had been produced elsewhere, but which had been selected especially for high yield. In general, the local varieties yielded as well as, or better than, the introduced varieties. This shows that with corn it is particularly important to obtain seed of a strain or variety adapted to the local conditions. Such seed can usually be obtained best by selecting ears from a local strain or variety which is known to have high yielding ability. It is almost always safer to take a chance on locally-grown seed corn than on seed introduced from a considerable distance, or seed which has been grown under widely different conditions.

Select Seed in Field

It has been emphasized repeatedly that seed corn should be selected in the field from standing stalks. It is only under such conditions that consideration may be given to the stalk which bears the ear. One of the prime requisites of high grade seed corn is that it be mature. By field selection it is possible to pick the ears only from those stalks which show evidence of maturing in a normal season. This is of particular importance at the higher altitudes. If a plant matures normally the husk on the ear becomes dry while the stalk and leaves are quite green. *Seed corn should always be selected before a killing freeze.*

It is preferable to select seed ears from corn that has been planted in hills rather than drill rows, because under the former conditions it is easier to pick out the superior plants that are superior because of their inheritance. A plant growing at the border of a field or standing alone may be superior because of the favorable circumstances for growth. Seed ears should be selected from superior plants which are growing in competition with other plants. *It is best to select seed ears from perfect stand hills surrounded by perfect stand hills.*

Corn is attacked by several diseases, the most serious of which are smut and the rots of the ear, stalk, and root. As the result of a study conducted a few years ago by the Illinois Agricultural Experiment Station it was estimated that where inferior and infected seed is used, losses to the corn crop from disease may be conservatively placed at 20 percent.*

There are numerous manifestations of diseased corn plants and such plants should be avoided in selecting seed ears. Plants which have a tendency to lodge as a result of decayed roots are likely to be badly diseased. Smut boils, premature ripening, stunted growth, and broken shanks are warning signals that should be heeded. A shredded or discolored scar where an ear is broken from the shank may indicate a diseased condition.

If a plant matures normally the husk on the ear will be dry while the leaves and stalk are still somewhat green and it is at this stage of maturity that seed selections should be made. It is well to

*Holbert, J. R., W. L. Burlison, Benjamin Koehler, C. M. Woodworth, and Geo. H. Dungan. Corn root, stalk, and ear rot diseases and their control through seed selection and breeding. Illinois Agr. Exp. Sta. Bul. 255:239-478, 1924.

select ears which have their tips well covered with husk as such ears are better protected than those with exposed tips. A heavy covering of husk over the entire ear affords some protection from the corn ear worm. *Seed ears should never be selected from stalks that show symptoms of disease.*

The object of selecting seed ears in the field is to increase yield or to maintain high yield already attained. In order to accomplish this, only vigorous, well-matured ears that are borne at a convenient height on the stalk should be selected. After the field selections have been made such ears as show obvious mixtures or abnormalities like flattened cobs should be discarded. It is usually advisable to select considerably more seed than will actually be needed for planting. Well-matured and well-cured two-year old seed corn is better than inferior one-year old seed. Then, too, it is usually easy to dispose of high-grade seed corn. *In the field, vigorous, matured ears should be selected regardless of type.*

The next step in obtaining desirable seed is to place the selected ears in a dry well-ventilated room as soon as they come from the field. The ears should be stored in such a way as to allow a free circulation of air around each ear. This may be accomplished by using any one of several types of seed corn hangers or "trees."

A satisfactory hanger may be made with woven wire and any two-by-four uprights. The woven wire, which should have meshes large enough to permit ears to be passed through easily from side to side, is fastened by two two-by-fours of suitable length and a convenient distance apart. One length of the woven wire is placed on each side of the uprights in a manner such that the complete rack resembles a double woven wire fence with the meshes opposite and four inches apart.

If stored in a dry, well-ventilated room, under ordinary conditions, seed ears will become sufficiently dry before they are likely to be injured by severe freezes. Sometimes it is advisable to use moderate quantities of heat (not above ordinary temperature in a living room) to facilitate curing. Excessive artificial heat should not be applied to seed ears, particularly if they are full of moisture, as the germination is likely to be lowered

As soon as they are brought from the field, seed ears should be stored in a dry, well-ventilated room in such a manner as to allow a free circulation of air around each ear.

Even though seed ears have been selected in the field and cured properly, it is not safe to assume that they will germinate vigorously. Each ear should be carefully tested by taking about six seeds from different parts of the ear and placing them in a germinator. A "ragdoll' which can easily be made with materials usually at hand serves well as a germinator. Such a tester may be made by cutting out a strip of muslin about eight to ten inches wide and about three feet long. Straight lines at intervals of two to two and one-half inches should be drawn with a pencil or crayon crosswise of the strip of muslin, and the rectangles formed by the lines numbered to correspond with the ear numbers. A piece of heavy wrapping paper of about the same size and shape as the strip of muslin will also be needed.

To make the germination test, the muslin should be wet and placed with the numbers face up on the strip of paper which previously has been placed on a table or flat surface. Next, a seed sample from each ear should be placed in its proper rectangle, arranging the seed in a single row about midway between the parallel lines. The seeds in each row should be spaced at about equal distances apart and the seed tips should all point in the same direction. The "long way" of the seed should be placed at right angles to the

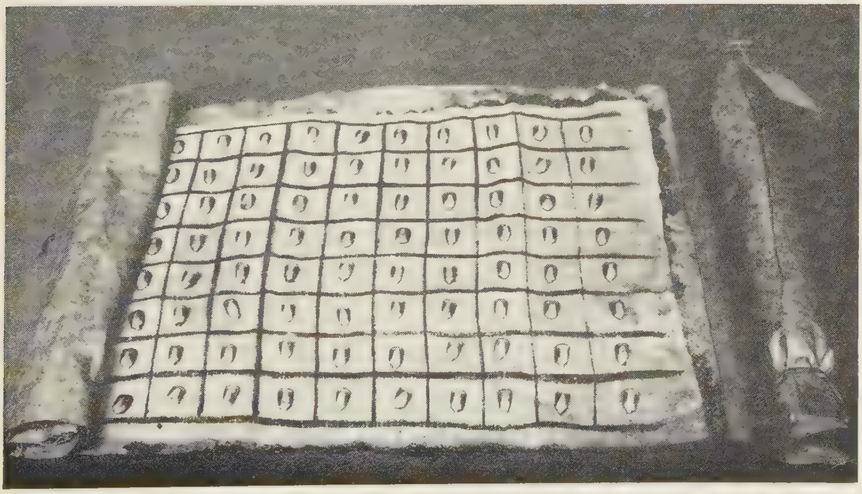


Fig. 8.—Two "rag dolls," the one at the right is rolled and fastened with rubber bands ready to be placed in water, the other one is partly rolled and shows the seed in the correct position. Each vertical row of seed represents a single ear.

"long way" of the muslin (See Figure 8).

After a sample of seed has been placed in each rectangle, the paper and muslin should be rolled up carefully and a rubber band placed around each end of the "doll." The "dolls" containing the corn should be allowed to soak in water for a few hours and then placed in an upright position so that all the seed tips are pointing downward. They should be kept in a warm moist container.

On the sixth or seventh day the seed may be examined and any ear whose seed sample shows weak or badly discolored sprouts, an abundance of mold, or any other symptom of disease should be discarded as well as those ears whose seed fails to germinate. After a strip of muslin has been used for a germination test it should be boiled for fifteen or twenty minutes before it is used again. *Each seed ear should be tested for germination before planting time.*

Ear-to-Row Breeding

A few years ago considerable prominence was give to continuous "ear-to-row" breeding as a method for producing high yielding seed corn. During recent years this method has been under investigation and the results show that the additional labor and expense involved do not justify its use. In no case has an increase in yield been demonstrated in a well-adapted variety by the use of continuous ear-to-row breeding. For the practical corn grower the selection of seed ears in the field from standing stalks according to the method outlined in this circular is much more satisfactory and probably just as likely to increase or maintain yield as any ear-to-row method.

Show Corn Versus Seed Corn

The ten-ear sample which is awarded first prize by the judge at a corn show is not necessarily the most valuable sample for seed purposes. Show corn does not mean seed corn, but unfortunately these terms are frequently confused. In show corn, uniformity of type is prized very highly, whereas in seed corn it is not as important. Such characteristics as maturity and freedom from evidence of disease and from varietal mixtures are desirable in both show and seed corn. A close selection for uniformity is not necessary for selecting good seed corn.

Show corn is valuable largely for its appearance, but seed corn, on the other hand, is valuable for what it will produce. It is impossible to ascertain with any degree of certainty the potential yielding ability of an ear of corn from its appearance. A vast amount of literature has been written describing studies of the relationship between ear characteristics and yield, but in no case has a close positive relationship been found. In other words, no ear characteristic is closely enough related to yield to have much value as an index of selection. A possible exception to this general rule is in the case of roughly indented, starchy ears. The Illinois Experiment Station has found that such ears are likely to be diseased and therefore should be eliminated.

It is not the purpose here to belittle the value of a corn show. There is no question but that these shows have served a very useful purpose in stimulating an interest in corn production. Where is the farmer who does not get a certain amount of satisfaction out of growing and selecting a prize winning sample of corn? *Nevertheless, it is important to keep in mind that the best show corn is not necessarily the best seed corn.*

A practical rack for curing and storing seed corn.


Raising
Dairy Calves
& Heifers
HENDERSON

RULES FOR RAISING DAIRY CALVES AND HEIFERS

1.—Leave the calf with its mother for the first two days after birth so that it will be sure to get the colostrum milk.

2.—Feed whole milk for at least the first two weeks.

3.—Make the change from whole milk to skim milk or milk substitute gradually.

4.—Weigh the feed to avoid overfeeding, as overfeeding is liable to result in scours. Keep the pails clean.

5.—Always give the feed at a uniform temperature. Use a thermometer.

6.—Feed small amounts of grain and hay as soon as the calves will consume them and gradually increase the amounts as the calves grow older.

7.—Tie the calves up, so that they can be fed separately.

8.—Keep calves and heifers growing normally at all times. (Note Table 30.)

9.—Grow heifers on as large amounts of pasture and roughages as possible; legume roughage is best.

10.—Do not breed heifers at too early an age, or they may never become full size.

Raising Dairy Calves and Heifers

West Virginia had approximately 219,000 dairy cows in 1928. The average age at which a cow is removed from the herd in the United States has been found to be about eight years. Accepting this age for West Virginia and assuming that a cow gives birth to her first calf at two and one-half years of age, and to one calf each year thereafter, which means the average cow can give birth to five calves in her life time, 43,800 calves must be raised every year in order to maintain the present number of dairy cows in the state.

Near the larger cities where the price of milk is high, many dairymen instead of raising calves, depend upon purchasing cows with which to maintain their herds. This method of herd maintenance has several disadvantages. Quite often the only cows that can be purchased are culls which the owner himself does not want, and if the best cows are purchased the price asked is usually very high. Furthermore, the buyer always runs a great risk of bringing diseases, such as tuberculosis and abortion, into the herd.

Herd improvement can best be brought about by replacing discarded cows with heifers of good breeding and type that have been well raised. Since it is a well known fact that the dairy cow inherits her milk producing ability, the surest and most practical way to improve a herd is for the dairyman to raise his own heifer calves from the best cows in his herd, using a good purebred bull for breeding.

Care of the Cow Previous to Calving

It has been said that "the care of the calf begins with the care of the cow." In any event, practice has proved that the best results are to be expected at calving time only when the cow is in good physical condition.

In order to have the cow in good physical condition she should be dried off six to eight weeks prior to time of freshing. During this "rest period" she should be fed a ration that is nutritious, laxative, and easily digested. Equal parts of corn meal, wheat bran, ground oats, and linseed meal make a satisfactory grain ration. When fed with silage and legume hay, this ration meets the requirements very satisfactorily. The feeding problem of a cow soon due to freshen is practically solved when the cow has access to good pasture for pasture grasses are nutritious and have the desired laxative effect. If the cow is very thin, however, she should receive from four to five pounds, or even more, of the foregoing grain mixture daily.

With proper care a cow's chances of calving normally and producing a healthy calf are greatly increased.

Care of the Cow at Calving Time

If the cow is confined to the barn, a few days previous to the time of calving she should be put into a clean, well-bedded, box stall. The stall should be of ample size for the cow to move around freely. During warm weather a clean grassy spot in the pasture field is a good place for calving.

About a week before the cow is due to freshen her grain ration should be reduced. Silage should be eliminated a week or so before calving. The feeding of a bran mash for the last few feeds before calving is recommended, as it has a cooling and laxative effect.

It is essential that the action of the cow's bowels be in a free and laxative condition at calving time. If there is any tendency toward constipation, 1 to 1½ pounds of Epsom Salts should be given the cow either as a drench or in the feed, at least a day or two before calving.

It is good practice to keep watch of the cow at calving time as a few minutes attention at this time may save the life of the calf. The experienced herdsman can calculate fairly closely as to when the calf will come, by noting the falling away on each side of the tail head, the loosening of the vulva, and the distention of the teats. Although it is not always necessary for the attendant to be present while the cow is calving, yet he should be near by so that he can give assistance in case it is needed.

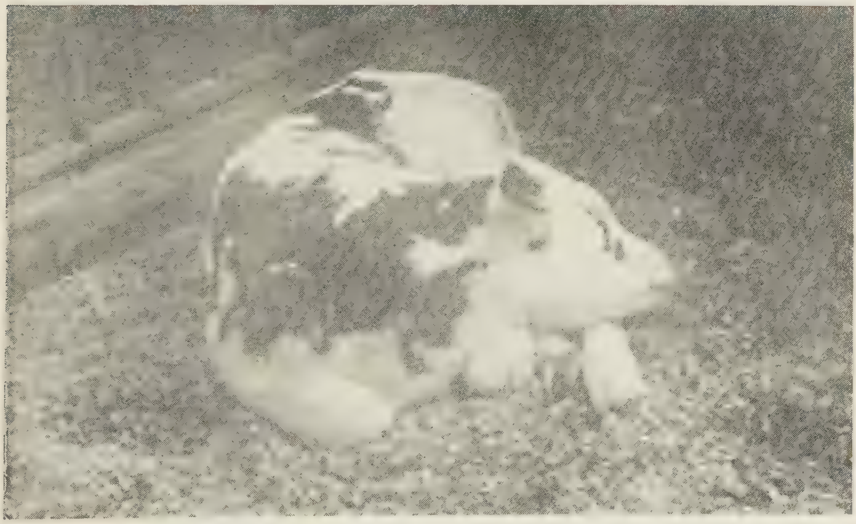
Care of the New Born Calf

If the cow calves normally, she will usually begin immediately to lick the calf. This aids in starting respiration, in improving the circulation, and in drying it off. In severe weather and when the mother fails to lick the calf, it should be rubbed briskly with a dry cloth or feed sack in order to hasten drying and to start the blood circulating rapidly.

Sometimes the foetal membrane covers the nostrils and completely shuts off the air. In such cases, the membrane should be removed promptly. It is always desirable to disinfect the navel of the new-born calf with a strong solution of creolin or other disinfectant, after which it should be washed with tincture of iodine. This precaution will prevent disease germs from entering through the navel.

A vigorous calf will attempt to rise in about fifteen to twenty minutes and usually will be nursing within half an hour. The weaker the calf is, the longer the time will be before it is able to get up and nurse. Occasionally some calves are unable to get up on their feet at all without assistance. In such cases it is necessary to aid them while nursing by holding them up to the cow's udder.

It is very important that the calf should receive the first or colostrum milk. This first milk is laxative and in addition has other properties which are essential to starting growth in the young calf.



The new-born calf should be carefully watched for the first hour, and in case it is not able to rise and nurse in that time, it should be given assistance. The colostrum milk is essential in starting growth.

In case of an unnatural condition in which the calf cannot receive the colostrum milk, a teaspoonful of castor oil should be given every two hours until there is a movement of the bowels.

Teaching the Calf to Drink

The calf should be left with the cow for two or three days to receive the colostrum milk, after which it should be removed and taught to drink milk from a pail.

The longer a calf is nursed by the mother, the harder it will be to teach it to drink from the pail. By instinct, a calf stretches its nose upward to receive its nourishment. In learning to drink from a pail, however, it must be taught to reach downward. No better way of teaching a calf to drink is known than the simple method of putting one's fingers in its mouth, and with one motion bringing its head into a pail containing a small amount of whole milk, so that its mouth comes in contact with the milk, and then carefully withdrawing the fingers, while holding its head down. It will probably be necessary to crowd the calf into a corner, and to stand astride of its neck, in order to teach it to feed in this way.

Some calves will learn to drink after the first attempt; with others it is quite a long process. It is usually best to omit the first

The first step in teaching a calf to drink from a pail.

The second step is to bring calf's mouth in contact with the milk and carefully withdraw the fingers while holding its head down.

feeding period so that the calf will be eager for its milk. It is desirable to use fresh whole milk for this purpose, and especially if the calf is young. Whole milk is best for the calf, and should be fed for at least the first ten days, if possible.

The milk should be fed at an even temperature of about 100 degrees Fahrenheit. The alternate feeding of warm and cold milk is likely to cause scours. During the second week the amount of milk can be slightly increased, provided, of course, that the calf is healthy. Within ten days or two weeks the gradual substitution of skim milk or other milk substitutes may be begun.

METHODS OF RAISING CALVES

Usually, whole milk is too expensive to feed to calves after they are ten days or two weeks old. In many sections of West Virginia cream or butter is the main dairy product sold and there is plenty of skim milk available on the farm for calf raising. Farmers thus situated are fortunate, and do not have a very serious problem in raising their calves. In other sections, whole milk is sold from the farm and hence little skim milk is available. On such farms the raising of

calves is somewhat of a problem. There has, however, been worked out definite, carefully tried, methods of feeding which take care of these different conditions.

Raising Calves With Skim Milk

CHANGING FROM WHOLE TO SKIM MILK

The calf should get a good start before the change from whole milk to skim milk is made. Usually it does not pay to begin feeding skim milk until the calf is ten days to two weeks of age and then the change should be made gradually. For the first day or two a pound of skim milk should be substituted for an equal amount of whole milk and then later larger amounts of whole milk can be replaced. It will usually require about a week to get the calf entirely on skim milk after which the amount of skim milk can be increased as the appetite of the calf indicates until 16 to 20 pounds are being fed at the time the calf reaches the age of six months.

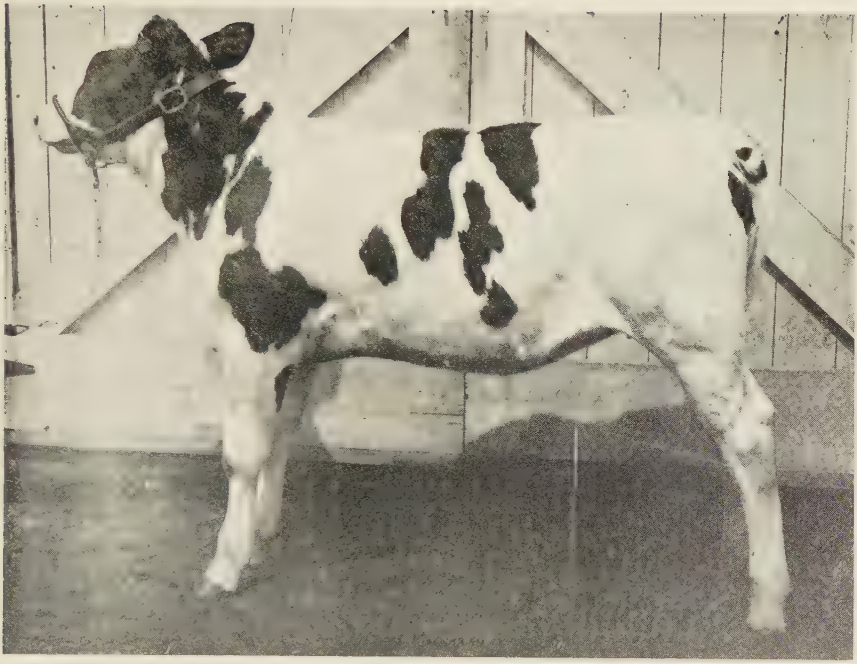
TEMPERATURE AND QUALITY OF THE MILK

The temperature of the milk is an important consideration, especially for very young calves. As previously mentioned, the skim milk should be warmed to about the temperature of milk fresh from the cow, which is approximately 100 degrees Fahrenheit. It is always well to use a thermometer to test the temperature. Judging the temperature by means of the finger cannot be relied on. When the calf is two or three months old, it is not so necessary to warm the milk, although even then calves can be raised with less digestive troubles if the milk is warmed. The feeding of warm milk at one feeding and cold milk at the next is very liable to upset the digestion of the calf.

In order to get the best results, skim milk should always be fed when it is fresh. There is no easier way to upset the digestive system of the young calf than by feeding sweet milk at one feeding and sour milk at the next. Sour milk can be fed successfully to calves, but extra precaution must be taken to make sure that it is always sour and of uniform quality.

If the skim milk is obtained from the creamery, it is very necessary that it be pasteurized before being fed to calves. Otherwise the milk may carry disease germs which might infect the herd. Most states have laws requiring such milk to be pasteurized, before being returned to the farmer.

Skim milk can well be fed for the first six months, and if the supply warrants, may be fed for even a longer period.



A well grown calf at four months of age that was raised on skim milk.

FEEDING GRAIN AND ROUGHAGE WITH SKIM MILK

It is at once recognized that when skim milk is fed, the milk fat must be replaced in its feed if the calf is to make normal growth. The calf should be induced to eat grain as soon as possible. Ordinarily the calf will consume a little grain at from two to three weeks of age. Corn is one of the cheapest of replacement feeds, and can be fed either cracked or ground until the calves are about six months of age after which it should be ground.

A grain mixture that has generally proved satisfactory consists of 3 parts cracked corn, 3 parts ground oats, 3 parts wheat bran, and 1 part linseed meal. Another good mixture is composed of 2 parts wheat bran, 2 parts ground oats, and 1 part linseed meal.

Many combinations of grains can be fed satisfactorily. The principal thing to bear in mind in selecting the grain ration is the necessity of obtaining a grain which will supply nutrients to replace the milk fat. At first only a small amount of grain should be fed. This amount should be gradually increased as the calf grows older. It is best to keep the calf's appetite keen rather than to dull it by over-

feeding. The use of scales in weighing the grain fed to calves is recommended.

Generally the calf will begin to eat hay about the same time it begins to eat grain. The calf should be allowed free access to the hay which should be leafy and of good quality. This should be fed at first in small amounts only and be put in fresh every day. Clover hay is one of the best roughages for calves. Alfalfa is good, also, but is slightly too laxative for young calves. When it is fed to young calves they should be watched closely to see that their bowels do not move too freely. The calf may be fed small amounts of silage after it is three months of age.

It has been calculated that under a system of liberal skim milk feeding the following amounts of feed will be required to raise a calf to six months of age:

Whole milk	12 to 25 gallons	Grain	150 pounds
Skim milk	260 to 350 gallons	Hay	500 pounds

A schedule to serve as a guide for feeding skim milk with grain from birth to six months of age is given in Table 1.

TABLE 1.—Daily Feeding Schedule for Calves Up to Six Months of Age With Skim Milk as the Major Feed.

Breed	Age of Calf	Whole Milk (Pounds)	Skim Milk (Pounds)	Grain (Pounds)	Hay
Jersey, Guernsey, or Ayrshire	1 to 3 days	With dam	....	..	....
	3 to 14 days	8 to 10	....	..	....
	2 to 3 weeks	10 to 1*	1 to 10†	⅛	Free access
	3 to 4 weeks	....	10	¼	Free access
	4 to 5 weeks	....	11	½	Free access
	5 to 6 weeks	....	12	¾	Free access
	6 to 8 weeks	....	13	1	Free access
	8 to 12 weeks	....	14	2	Free access
	12 to 24 weeks	....	16	3	Free access
Holstein, Brown Swiss, or Shorthorn	1 to 3 days	With dam	....	..	....
	3 to 14 days	10 to 12	....	..	....
	2 to 3 weeks	12 to 1*	1 to 12†	⅛	Free access
	3 to 4 weeks	....	12	¼	Free access
	4 to 5 weeks	....	14	½	Free access
	5 to 6 weeks	....	15	¾	Free access
	6 to 8 weeks	....	15	1	Free access
	8 to 12 weeks	....	16	2	Free access
	12 to 24 weeks	....	16 to 20	3	Free access

*Gradually decreased. †Gradually increased.

WHEY AND BUTTERMILK FOR CALVES

The analysis of buttermilk is very similar to that of skim milk and so the same supplements that were used with skim milk can be used successfully in raising calves on buttermilk. On most farms, however, where buttermilk can be obtained skim milk is also available. As a rule, it will be found that sweet skim milk grows a better and thriftier calf than does buttermilk or sour milk. Some experiments, however, show that calves fed buttermilk are less subject to scours than those fed skim milk.

Whey has a higher percentage of water, a much lower amount of protein, and about the same amount of fat and sugar as does skim milk. When whey is fed the grain mixture supplement must contain a high percentage of protein. Linseed meal is often mixed in the whey as a gruel. If whey must be fed, it should not be fed until the calf is five or six weeks old. After that age good calves can be raised on whey, provided the whey is supplemented with the proper concentrates and the calves are given the best of care and attention.

Raising Calves With But Little Milk

On many farms where whole milk is sold there is little or no skim milk available for calf feeding. Under these conditions there are two methods which may be followed satisfactorily in the raising of calves. These methods are: (1) Raising calves with a minimum amount of milk; and (2) Raising calves with milk substitutes.

THE MINIMUM AMOUNT OF MILK METHOD

This system of calf raising has been used successfully at many of the experiment stations and on dairy farms. The method consists of giving the calves a good start on whole milk or whole milk and skim milk for about two months after which their ration consists entirely of hay and grain. The secret of the success of this method is to give the calves a good start before they are weaned from the milk. The calves should also be fed as much milk as they can handle up to 15 or 16 pounds daily, depending upon their size and condition. If they are large, vigorous calves the milk may be omitted from the ration at about two months of age, but for less vigorous animals the milk should be continued a few weeks longer.

It is essential, under this system, that the calves be taught as soon as possible to eat grain and hay, which should be fed liberally. The grain mixtures and roughage used under this method may be the same as those recommended for calves raised on skim milk.

Good healthy calves can be raised by this method, but ordinarily they are not quite as well grown at six months of age as are those that are fed milk. Experiments and practice have shown, however, that calves raised under this system when well fed will be as large at time of freshening as those fed skim milk until six months of age.

It has been calculated that under the "minimum amount of milk method" the following amounts of feed will be required to raise a calf to six months of age.

Whole milk	24 to 30 gallons	Hay	400 to 500 pounds
Skim milk	70 to 80 gallons	Grain	500 pounds

MILK SUBSTITUTES

Calf Meals.—Raising calves satisfactorily on calf meals has been demonstrated as possible, but results have shown that it is more difficult than when whole or skim milk is used. The calf meals are not as easily digested as milk or milk powders and more care must be taken to avoid digestive disorders. There are several proprietary calf meals on the market. When these are fed the directions of the manufacturer should be followed closely. Several experiment stations have experimented with home mixed calf meals. Probably the simplest one, giving good results, is the one recommended by the Purdue Experiment Station which is as follows:

Linseed Meal
Hominy Feed
Red Dog Flour
Dried Blood
} Equal parts by weight

The calf meal is fed in the form of a gruel. When the calf is a week to ten days of age a small amount can be mixed with the milk. The amount can then be increased gradually and mixed with water in the proportion of one part of meal to seven parts of water and fed at a temperature of about 95 degrees Fahrenheit. The feeding schedule given in Table 2, which is based on recommendations made by Swett* will serve as a guide in the feeding of calves on calf meal.

Dry Skim Milk, Dry and Semi-Solid Buttermilk.—Sometimes it is almost impossible, or at least very inconvenient for the dairyman who sells his milk to provide even a small amount of skim milk for calf feeding. In such cases it has been found that skim milk powder, buttermilk powder, or semi-solid buttermilk can be used satisfactorily in the place of skim milk. Dried skim milk is perhaps the most satisfactory. In preparing it for use, it should first be made in the form of a thick paste with a small amount of water and stirred until all the

*Cir. 88, Mo. Agr'l Exp. Sta.

TABLE 2.—Daily Feeding Schedule for Calves Up to Six Months of Age, With Calf Meal as the Major Feed.

Age of Calf	Milk (Pounds)	Gruel (Pounds)	Grain (Pounds)	Hay
1 to 3 days	Leave with dam	..	....	....
3 to 14 days	10	..	....	....
2 to 3 weeks	9	1	....	....
3 to 4 weeks	9	3	⅛	Free access
4 to 6 weeks	6	6	¼	Free access
6 to 8 weeks	....	12	½	Free access
8 to 12 weeks	....	14	1	Free access
12 to 16 weeks	....	14	2	Free access
16 to 20 weeks	....	..	4	Free access
20 to 24 weeks	....	..	4½	Free access

lumps are eliminated. It can then be mixed with water in the proportion of one part of the powder to nine parts of warm water and fed in the same way, and in the same amounts, as ordinary skim milk. In fact it can be fed alternately with ordinary skim milk without in any way affecting the digestive system of the calf. This is an advantage to the dairyman who may have a surplus of milk at one time and a shortage at other times, since he can keep some dried skim milk for periods of shortage.

Powdered buttermilk can be used in the same way but greater care must be used in starting the calves on it, on account of its acidity. Semi-solid buttermilk can also be used, but it is not as satisfactory as the dried, especially in the summer as it will not keep so well. It should be mixed with about three times its weight of warm water.

These products are usually higher in price than skim milk but are not as high as whole milk.

Management of Calves

A regular routine should be followed in the feeding of calves as with all dairy stock. The milk feeding pails should be washed after each feeding since dirty pails are usually the source of many digestive disorders. Metal pails with well soldered seams should be used as they are much easier to keep clean than wooden pails. The mangers should be kept fresh and clean.

The pen for young calves should be warm, dry, and well bedded, especially under winter conditions. Stanchions should be provided in which to fasten the calves when being fed milk. Otherwise, all may

A poor method of feeding calves that should not be followed. Often some are crowded out and do not get their share, and sucking is encouraged. Stanchions as shown on the cover of this circular are recommended, with a trough for feeding grain immediately after the milk.

not get their share of feed, and furthermore, they may learn to suck one another. The feeding of grain just after the feeding of milk while they are still fastened in the stanchion will also aid in preventing the sucking habit.

Digestive disorders are the most common of calf ailments and can be controlled largely by feeding warm milk (95° to 100° F.) in clean pails, always being careful not to overfeed milk or grain. The calf should have free access to both water and salt. With the exception of freedom for exercise there is little advantage in pasture for calves under six months of age.

RAISING THE HEIFER

From Six Months to Freshening

The first six months constitute by far the most expensive period in raising dairy calves. This is true both from the standpoint of cost of feed and labor. After calves have reached six months of age they do not require as much attention as before. The main consideration then is to keep them growing normally.

FEEDING GRAIN AND ROUGHAGE

Growing heifers are unproductive, and every dairyman wants to raise his heifers as economically as possible. Generally speaking, the roughage is the cheapest part of the ration, and dairy cattle are adapted to using relatively large amounts of roughages. Hence, one of the first considerations is to supply the heifers with as much roughage as they will clean up. Legume roughages have the advantages that they supply larger amounts of protein and also of mineral matter than the other roughages. Silage furnishes an economical part of the ration for dairy heifers. Experiments have shown that legume hay and silage when fed together make a combination which gives satisfactory growth, but maximum growth cannot be obtained where either of these feeds are fed alone.

The addition of grain to the ration of growing heifers under ten months of age has proved to be a paying proposition. This is especially true of the period following weaning from milk. If grain is discontinued after the calves are taken off skim milk, they will not continue normal growth. One of the most satisfactory rations for this period consists of 100 pounds corn meal, 100 pounds of wheat bran, and 100 pounds of linseed meal.

The following practical winter rations, recommended by Eckles,* have proved quite satisfactory.

1.—When silage and legume hay is on hand, or can be purchased economically, the ration suggested is as follows: Corn silage and alfalfa, clover, cowpea, or soybean hay at will; and for animals less than ten months old two pounds of grain daily in addition. The grain fed may be corn, or a mixture of other grains if the cost per pound is less. For heifers within three months of calving, two to five pounds of grain should fe fed daily, depending upon condition. The object is to have them in good flesh at calving time.

2.—When corn silage is on hand, but no legume hay, a satisfactory ration is silage at will for roughage, with some dry feed, such as hay or fodder. Two or three pounds of concentrates should be fed daily, one-half of which should be a high protein feed such as gluten feed, linseed meal or cottonseed meal. The remaining half may be corn, oats, bran, or any other mixture, if cheaper per pound than corn.

3.—When an abundance of legume hay, but no silage, is on hand a satisfactory ration is alfalfa, clover, cowpea, or soybean hay at will, and two pounds of corn daily. Other grains may be sub-

*Bul. 158, Mo. Agr'l Exp. Sta.

stituted with economy if the cost per pound is less than corn. On a ration of legume hay dairy heifers will do fairly well but will not make a normal growth. It is believed to be economical, as a rule, to feed a limited amount of grain in addition.

4.—When corn fodder, kafir fodder, or timothy hay is on hand, but no silage or legume hay, it is generally best to purchase legume hay. The suggested ration is legume hay one-half, timothy hay one-half and corn fodder at will. With this should be fed a grain mixture composed of one part gluten feed, cottonseed, or linseed meal, and two parts corn. Other concentrates may be used in place of corn if the cost per pound is less.

If legume hay cannot be purchased, more grain must be fed for even fair results. Under these conditions the ration suggested is: Hay and fodder at will, with five pounds daily of a grain mixture composed of one part corn, one part bran, one part cottonseed meal, linseed meal, or gluten meal.

Two or three months prior to calving the heifers should receive additional grain. A good mixture during this time is made up of equal parts of corn meal, ground oats, wheat bran, and linseed meal.

Experiments at the West Virginia Agricultural Experiment Station, which check with those of other stations, show that it does not pay to feed heavy grain rations to heifers during the winter feeding period. The heifers which make big gains during the winter generally do not gain as much during the pasture season as those which make only average gains during the winter. It has been found that the heifers making normal gains in the winter show more gain the next summer on pasture than do those that make a big gain in the winter.

PASTURING

Fall calves can be turned on the pasture the following spring, but spring calves, as they do not get much benefit from pasture the first summer, need not be turned to pasture excepting for exercise. With calves six to ten months of age it is desirable to feed some grain even on good pasture, as the digestive system of the young heifer has not been developed to handle as large amounts of grass as are necessary to furnish the nutrients for proper growth. In other words the calves can not consume enough grass to keep them growing steadily.

Many farmers make the mistake of turning the calves on pasture too early in the spring. By all means, the pasture should have a good start before the herd is turned on. Often during August the pasture becomes dry and scarce. During this hot and dry period the pasture should be supplemented with a small amount of grain.

NORMAL GROWTH

The main considerations in the management of heifers from six months to freshening is to see that they are attaining proper growth. Table 3, which was prepared by Eckles, is included as a means of checking the normal growth of dairy heifers.

The ration should be such that the heifers will make at least normal growth for the breed. Many dairymen are obtaining growth

TABLE 3.—Normal Weight and Height at Withers of Females During Growing Period.*

Age (Months)	Holsteins		Jerseys		Ayrshire	
	Normal Height (Inches)	Normal Weight (Pounds)	Normal Height (Inches)	Normal Weight (Pounds)	Normal Height (Inches)	Normal Weight (Pounds)
Birth	28.3	90	26.0	55	....	69
1	30.2	121	27.7	76	27.5	90
2	32.3	157	29.4	105	29.5	128
3	34.2	200	31.2	140	31.2	170
4	36.2	249	32.9	174	33.1	218
5	38.0	302	35.1	222	35.1	254
6	39.7	349	36.9	260	36.4	286
7	40.9	389	38.1	302	37.3	304
8	42.2	425	39.3	340	38.5	336
9	42.9	466	40.5	376	39.0	366
10	43.8	501	41.3	407	39.6	406
11	44.3	529	41.9	432	40.1	427
12	44.8	558	42.6	456	40.7	456
13	45.6	574	43.3	480	41.3	485
14	46.2	596	43.8	503	42.0	533
15	46.8	612	44.4	520	42.4	547
16	47.4	643	44.6	533	42.7	560
17	47.7	660	45.1	553	43.1	579
18	47.9	686	45.5	572	43.7	604
19	48.3	715	46.0	598	44.2	627
20	48.7	746	46.3	621	44.6	651
21	48.9	774	46.5	649	44.9	679
22	49.2	796	46.8	668	45.4	707
23	49.5	824	47.2	689	45.6	733
24	49.8	841	47.4	716	45.9	759
25	50.2	869	....	737	46.6	798
26	50.5	893	....	758	46.7	807
27	50.9	925	48.0	770	46.8	859
28	51.1	966	....	784	46.9	...
29	51.3	994	....	804	47.0	...
30	51.5	1021	48.3	...	47.2	...

*Res. Bul. 36, Mo. Agr'l Exp. Sta.

above the normal. The height and weight should be checked occasionally to see that the heifers are at least maintaining normal growth.

Age of Breeding

The mistake is often made of breeding heifers when they are too young. This should be avoided for heifers that are bred too early seldom make large cows. This is due to the fact that the production of milk is such a heavy drain upon the animal that it is impossible for her to make normal growth. Generally speaking, the largest cows of the breed are the heaviest and most profitable producers

The following schedule will serve as a guide in determining the age to breed heifers:

Holsteins	19-23 months	Guerneys	17-20 months
Ayrshires	18-21 months	Jerseys	15-18 months

COMMON CALF AILMENTS

Common Scours

Common scours is one of the most common of calf ailments. The most frequent cause of scouring is overfeeding. If the calves have not been overfed, then the condition can likely be traced to feeding from dirty pails, feeding cold and warm milk alternately, feeding sweet and sour milk alternately, or feeding milk too rich in fat.

Prevention of this trouble is easier than its cure. In its treatment, however, first, all feed should be reduced. A dose of castor oil (1 to 3 ounces) should be given in order to move the bowels properly. This may be followed by one teaspoonful of a mixture of equal parts of Salicylic acid and tannin, twice daily until the symptoms are relieved. Hand-fed calves should have lime water (one tablespoonful) added to each quart of milk fed. Care should be taken in getting the calves back on full feed, so that they will not suffer another attack.

White Scours

White scours is an infectious disease caused by a germ which enters the body most frequently through the digestive tract. Most calves which contract this disease will die as there are no medicinal cures known at the present time. It is recommended, however, that anti-white scour serum be injected into all calves, immediately after birth on farms where this disease exists. At the first suspicion of the disease a competent veterinarian should be called. Prevention is the best means of combating it. All cases should be isolated, the carcass of all dead calves should be burned, and the stables thoroughly disinfected.

Pneumonia

Pneumonia is brought on by chilling and is sometimes associated with calf scours. It is characterized by lack of appetite, rapid breathing, constipation, with high temperature, 105 to 106 degrees Fahrenheit. An experienced veterinarian should be called. The calf should be blanketed, and placed in a clean well ventilated box stall which is free from drafts. A mustard plaster may be applied over the lungs and a laxative given to keep the bowels open.

Ring Worm

This disease is caused by a parasite which forms ring-like spots on the skin, usually on the neck, shoulders and rump. The hair comes out and scales form. These scales should be removed by washing with soap and water using a stiff brush. The spots should then be painted with tincture of iodine.

Lice

Calves that are badly infected with lice will not make good gains. Spraying or brushing infected animals with a 2 percent solution of creolin is a fairly effective means of ridding animals of lice. These treatments should be repeated at intervals of from four to five days until the lice are eradicated. A mixture of one-half of a pint of kerosene and one pound of lard can be applied in weather too cold to allow washing or spraying. This treatment can be repeated as often as necessary.

FITTING AND SHOWING CALVES AND HEIFERS

The exhibiting of livestock is an old practice and was probably established because of the advertising and educational value derived therefrom. At the present time each of the dairy breeds has a pretty well defined type set up as a standard. Any dairy animal exhibited should conform very closely to its breed type, if the exhibit is to have any advertising or educational value.

In the practice of preparing animals for the show ring, the methods of feeding and care are somewhat different from those followed in every day herd practice. Each exhibitor wants his animals to appear to their best advantage.

Feeding

The feeding of show animals is important if the best showing is to be made. It is not desirable to have dairy animals excessively fat for exhibition purposes. It is, however, desirable for the animal to carry a fair amount of flesh as a very thin animal does not present a

pleasing appearance. The animal that is reduced in flesh will require a longer fitting period than one that is well nourished. This fact should be borne in mind when one selects animals for the show ring. There are many different rations that have been recommended in fitting show animals, but the following is probably one of the simplest and has given good results:

Wheat Bran Ground Oats Corn Meal Linseed Meal	Equal parts by weight

This ration should be fed with good legume hay and silage or beet pulp. If the animal is thin in flesh, more corn meal should be added. The amount of grain to feed will depend upon the size, individuality, and condition of the animal. As a general rule, feed one-half pound of grain for each 100 pounds live weight. This amount should be increased one-fourth of a pound every second day as long as the animal cleans up its feed with relish. Towards the end of the fitting period, beet pulp should be substituted for silage, as silage is difficult to obtain on the show circuit and it is best to have the animal on the same feed it will receive during the exhibition period.

Clipping

If the hair is very long the animal should be clipped all over. This should be done three or four weeks before time of showing. Even, smooth, clipping is an important operation, for a nice sleek coat adds greatly to the attractiveness of the animal. Just before showing time, the animal should be clipped lightly around the head, along the belly, udder, and tail. After clipping, the coat should be given a thorough rub-down with sand paper which will cause the hair to lie closely to the body.

The animal should never be clipped and turned out in the sun as this will make the hair rough. For at least a month before exhibition, the animal should be kept in the stable out of the hot sun.

Brushing

Brushing stimulates the circulation of the blood which aids digestion and helps to make a glossy coat of hair. A mellow skin is evidence of good feeding and thorough brushing and denotes good condition. A common horse brush can be used, although a stiffer brush is sometimes to be preferred. The brushes should always be kept clean.

Washing

Frequent washing is another means of obtaining and maintaining a good condition of skin and hair. In washing, plenty of water and soap should be used, always being careful to rinse out all the soap. To make the switch clean and fluffy, it should be washed in soap suds and rinsed in water to which a little bluing has been added. The wet braid should be tied tightly and kept tied over night and then combed and fluffed out. An animal on exhibition should be spotlessly clean.

Blanketing

The animal should be blanketed after washing in order to keep the coat clean and the skin in good condition. Blanketing raises the temperature of the body and retards the hair growth somewhat. It also helps make the coat smooth. Hence, in order to get the most satisfactory results from clipping, the animal should be blanketed.

The Hoofs and Horns

In addition to the hair, the hoofs and horns of an animal have an important effect upon its appearance. The hoofs should be trimmed, properly shaped, and polished. The horns should be scraped and polished. This can probably be done best with a rasp, sand paper, and emery cloth, and shoe polish or linseed oil applied with a flannel cloth as a final touch.

There seems to be little doubt but that an animal with horns shows to a better advantage than one that has been dehorned. Sometimes the horns do not grow in the proper shape which detracts from the appearance of the animal. This defect can be overcome by the use of horn trainers which can be purchased from various supply firms. It should be remembered, however, that the trainers must be used while the horns are growing.

Showing the Animal

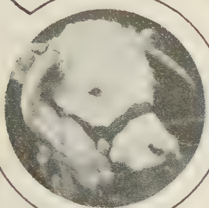
Any show animal should lead readily and stand in a position that will display its good points. The younger the animal the easier it can be taught to lead and stand properly. With any age, however, a large amount of time is required to train an animal to lead, back, stand, and respond to the slight pressures by means of which the trainer indicates a change of position. There are many points in posing an animal which can be learned only through showing. The important thing to remember, however, is that part or all of the effort spent in fitting an animal may be for naught, unless it is properly trained.

If the calf or heifer is to show well in the judging ring, it must be trained to lead and stand as the showman desires.

CIRCULAR 53

NOVEMBER, 1928

BUILDINGS AND EQUIPMENT FOR THE LIVESTOCK FARM

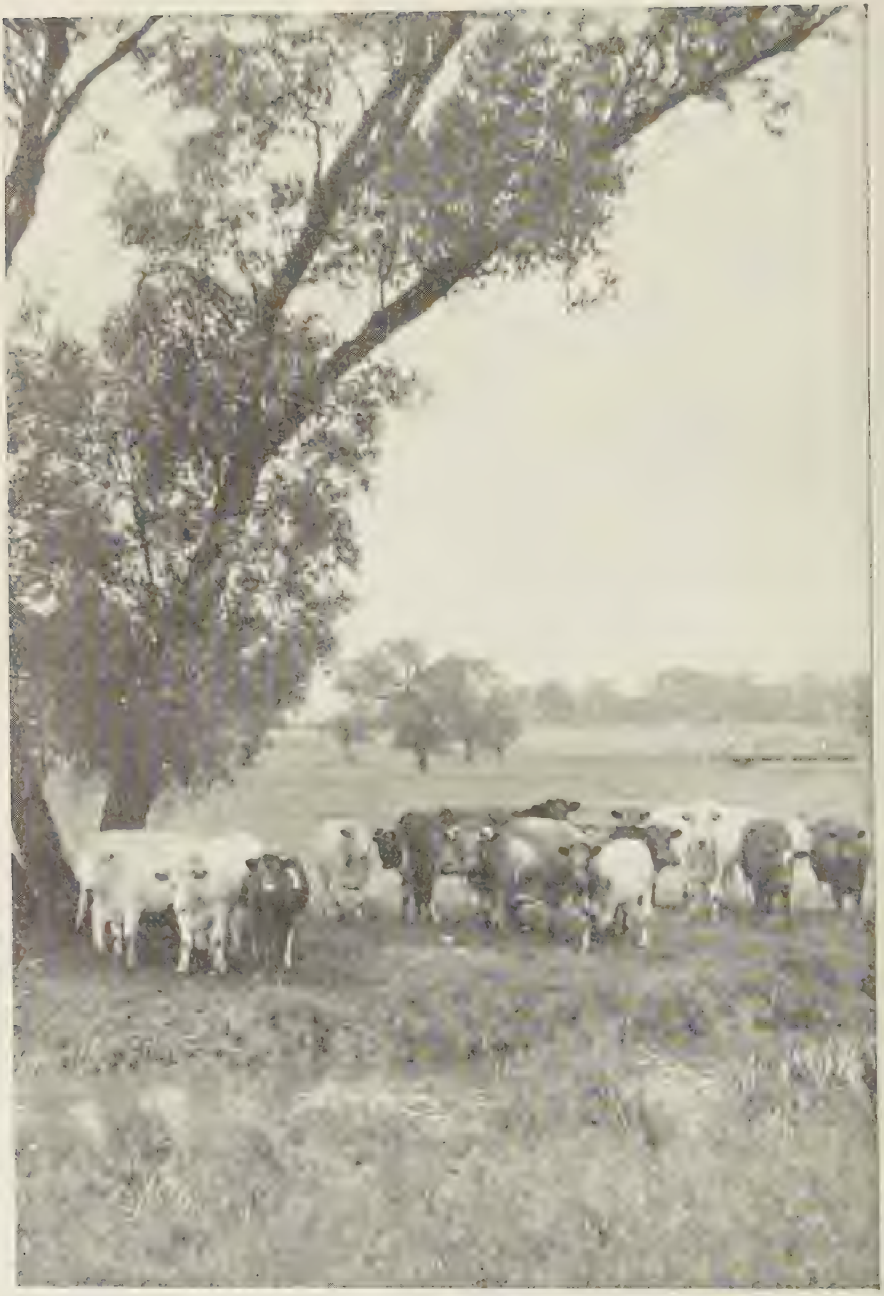


BY

F. D. CORNELL, JR.

AGRICULTURAL
EXPERIMENT STATION
COLLEGE OF AGRICULTURE

WEST VIRGINIA
UNIVERSITY
MORGANTOWN



The raising of beef cattle is an important farm enterprise in many sections of West Virginia.

Buildings and Equipment for the Livestock Farm

In the development of the livestock industry, the care and housing of animals has come to play an important role. It is only necessary to call attention to the part played by proper housing and equipment in obtaining the most economical gains from feeds, in making possible efficient breeding and care of livestock, in promoting the health of animals, in bringing about lowered mortality among young animals, and in other similar phases of the industry, to realize the truth of this statement.

West Virginia, because of her topography and abundance of bluegrass pasture, has long been a livestock producing state. The type and breeding of the beef cattle produced are constantly being improved with the result that many excellent herds of purebred cattle may now be found in the state.

Sheep, too, are kept in large numbers in some sections of the state. The Northern Panhandle section produces many fine-wool sheep. In other sections of the state, coarse-wool breeds are raised in large numbers. All of these are being improved through more careful breeding and management.

Hog raising in West Virginia, up to the present time, has been largely for home consumption. The greater percentage of the hogs raised are killed on the farm. Hog raising, however, is an important phase of the livestock industry in West Virginia, as is shown by an increase of 38,000 head on January 1, 1928, over the 1927 figure.

It is with the hope of partially meeting the needs of those engaged in the livestock industry in West Virginia for information on adequate buildings and equipment that the following plans and discussions are presented.

BUILDINGS AND EQUIPMENT FOR BEEF CATTLE

Of the farm building problems that have received attention, as little has been paid to the construction of beef cattle barns and the economics of housing beef cattle as to any building problem on the farm. Nevertheless, enough has been done to show conclusively the advantages of the proper housing and care of beef animals through the winter months.

When one stops to realize the narrow margin upon which the livestock feeder operates, the proper housing for more efficient utilization of feed and labor assumes economic importance. "There is an appeal to the pocket as well as to the sympathy in the lowing of the shivering herd."

Numerous experiments have proved that adequate shelter reduces feeding costs. Less feed is required to maintain the animal heat when the animals are sheltered, and waste is materially reduced. The feed not eaten is left dry and palatable. Prevention and control of disease are made possible. Proper housing also conserves manure and is of importance from the viewpoint of convenience and labor saving. Economies in labor mean returns in dollars, and this is especially important in the feeding of beef cattle under present conditions.

There is little question, therefore, that housing facilities and equipment for beef cattle do have an important economic significance.

Classification of Shelters

Beef cattle shelters may be classified in two general groups, or as natural and artificial. Natural shelters include hills and valleys, timber, and any other natural windbreak or protection. Artificial shelters comprise constructed windbreaks, various types of straw shelters, fences, stacks, pole and board shelters, baled straw shelters, temporary board shelters, sheds, and barns.

Barns vary in type, but those in general use may be classified as pole, lean-to shelter, gambrel, (stable 30 to 42 feet wide), gothic roof, (stable 30 to 42 feet wide), round, monitor, and wide (more than 42 feet).

Essentials in Construction

There are a few essential points which should always be kept in mind when planning a beef cattle barn. These are: convenience, serviceability, durability and economy, sanitation, and appearance.

CONVENIENCE

Convenience is probably the most important of the essentials in the construction of a beef cattle barn. In it is embodied an important share of the profitableness of the beef cattle enterprise. This feature means convenience of location with reference to other buildings and to pastures. It also means a well-planned interior arrangement so that feeding and cleaning may be accomplished with a minimum expenditure of time and effort. Through the reduction of labor costs, profits may be materially increased. The livestock feeder operates

on a narrow margin between the prices of finished and unfinished steers and any reduction in the cost of finishing the product for market aids in producing a profit on the enterprise.

SERVICEABILITY

The feature of serviceability means a barn design that will give maximum utility the year around. Since most beef barns are used intensively for housing beef cattle only a few months in the year, the barn should be designed so as to be adaptable for other uses such as the housing of other livestock, or machinery.

DURABILITY AND ECONOMY

To obtain a good beef cattle barn with maximum life and a minimum initial cost and upkeep, construction details must be carefully considered. Cost considered from the standpoint of probable durability rather than immediate outlay results in economy in building construction. If initial cost only is considered, it will often be found that after a lapse of time a cheap structure proves to be relatively expensive, due to excessive repair and upkeep costs.

SANITATION

While sanitation is not as important in a beef cattle barn as it is in a dairy barn, it is important, however, that the barn be well lighted and ventilated, and so constructed that it may be easily cleaned. It should be located on a well-drained site to insure freedom from excessive mud in the barn lot and dampness in the stable. The location of the barn is important from two viewpoints. First, it should be located convenient to pasture and feed lots, and also conveniently near the other buildings in order to effect savings in time and labor in doing the farm chores. Second, the site should be well drained. If there is not sufficient natural drainage, sub-surface drains should be installed before the building is erected.

APPEARANCE

In obtaining the foregoing features, the appearance of the barn should be kept in mind. The essential features may be as easily embodied in a structure of pleasing appearance as in one that is not. The advertising value alone of a neat and attractive building is worth while.

A Steer Barn for West Virginia*

It is rather difficult to establish definite limits in building construction beyond which the owner may be said to be exercising ex-

---

*For a discussion of barn framing see West Virginia Agricultural Experiment Station Circular 49.

travagance and adding no appreciable utility to the structure. The whole problem must always be solved by sound judgment and common sense.

The Animal Husbandry Department of the College of Agriculture advocates an open shed type steer barn for West Virginia, with ample storage space overhead, on the ground that this type of building will give maximum returns at a minimum cost. This recommendation is made after considerable experience and experimental work in housing steers under West Virginia conditions.

The points which recommend the open shed barn are: the cheapness with which it may be constructed, the low upkeep and maintenance cost, the satisfactory results that may be obtained in feeding under West Virginia climatic conditions, and its adaptability for use in housing other livestock or machinery when not in use for beef cattle.

Storage space for feed should always be provided, as it is the feeding operation which requires the greater percentage of time and cost. By reducing this cost to a minimum, one may materially increase his profits.

In working out the building plan, several points should be kept in mind. The first is to allow ample floor space so that the animals may move about or lie down in comfort. Where pens are used, as in a herd barn, a floor space of 40 square feet for each mature animal is recommended. With the open shed steer pens, this allowance can be reduced to 30 square feet per mature animal. This will guarantee the animals comfort and ample shelter even in the more severe weather. Plenty of feed rack space should also be provided since the best results can never be obtained by crowding the steers at the feed rack. An allowance of at least 30 inches of rack space per animal should be made. The height of the stable should be 8½ to 9 feet since manure is often left to accumulate to a depth of 6 to 12 inches in a barn where beef animals are kept.

The best floor for this type of barn is concrete, well covered with litter. This gives a dry floor, one that is easily cleaned, conserves manure, and is durable. Concrete also prevents the objectionable muddy condition that might otherwise exist at times. For these reasons, a concrete floor is desirable, although not absolutely essential.

Feed racks should be arranged for convenience in feeding and provision should be made so that cleaning may be done quickly and easily.

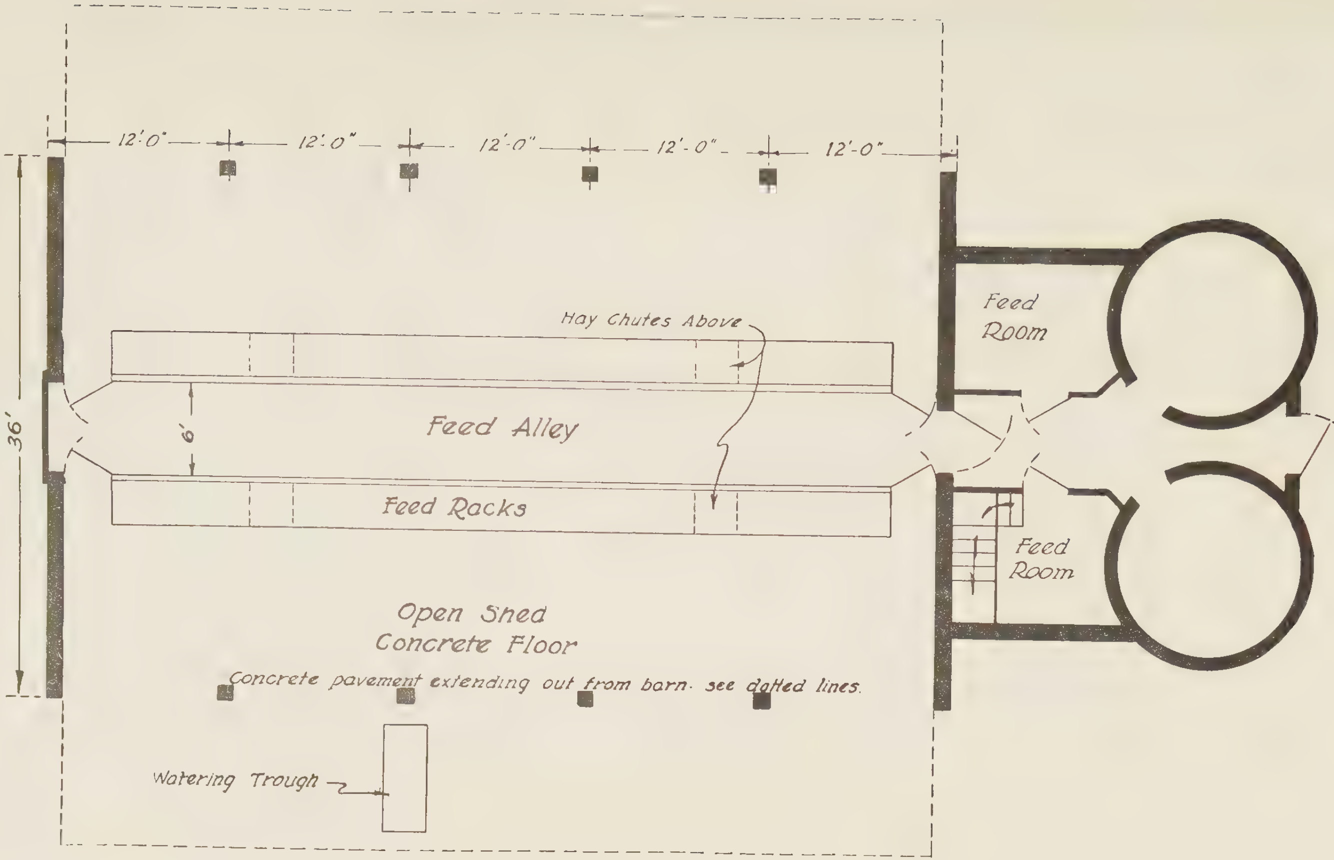


Fig. 1.—Floor plan of open shed steer barn.

Figure 1 shows a plan of an open shed type steer barn designed to accommodate 50 head. This plan may be modified to meet individual needs by changes in dimensions, arrangement, or construction details.

A Herd Barn for West Virginia

Where both breeding and feeding of beef cattle are carried on, a barn of somewhat different nature from an open shed feeding barn is desirable. This building need not, however, be an elaborate structure.

A combination barn, that is, a barn with one side closed, along which cow, calf, and hospital pens are arranged, and with open shed feeding pens on the other side, works satisfactorily under West Virginia climatic conditions. By adopting this plan, an open shed steer

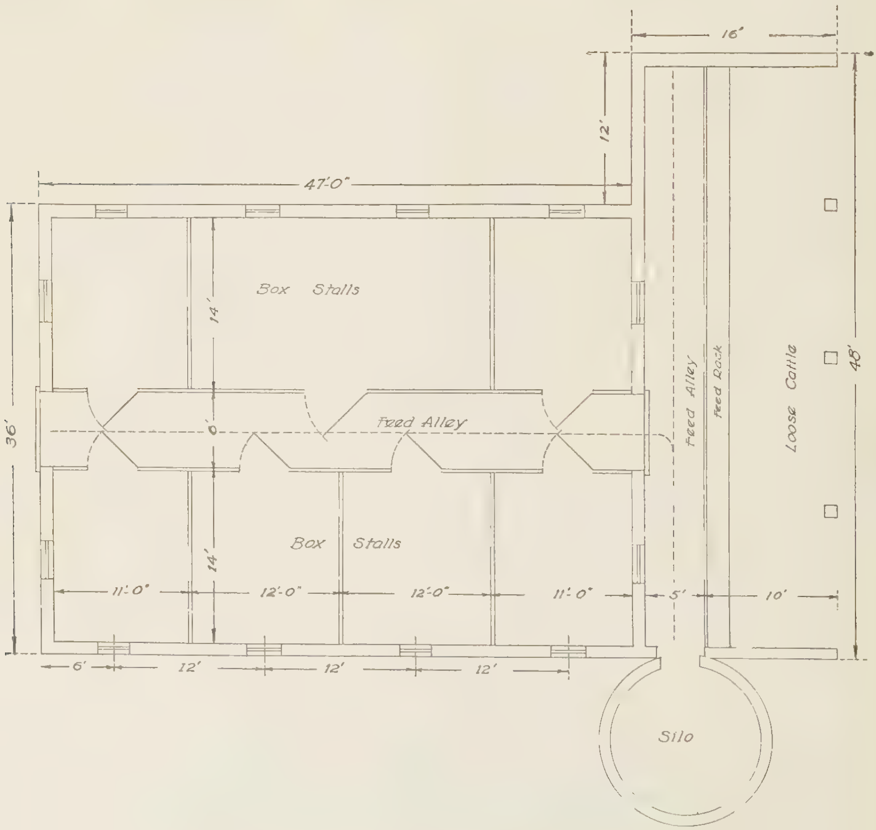


Fig. 2.—Floor plan of herd barn combining the enclosed pen and open shed features.

barn may be readily converted into a herd barn at little expense. If more pen space is required than can conveniently and economically be arranged along one side of the barn, a herd barn may be built, inclosed on all sides, and a wing of the open shed type added for feeder cattle. Figure 2 shows the floor plan of such a barn. The essentials of convenience, space, light, ventilation, and sanitation apply in both types of structures.

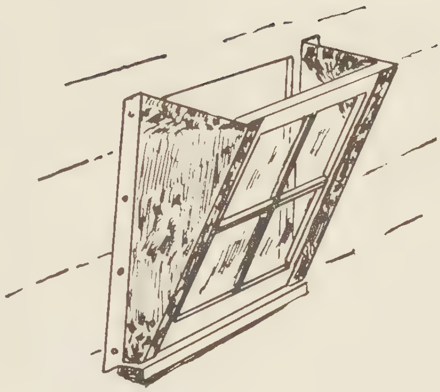


Fig. 3.—Detail showing common method of hanging windows in the stable.

A ventilating system is not an essential feature in beef cattle barn construction in this state. The open shed barn, of course, is amply lighted and ventilated. The herd barn, too, may be ventilated sufficiently by opening doors and windows. The windows should be hung as shown in Figure 3. In latitudes where the temperature seldom falls below zero, this method of ventilation is advisable. Where such climatic conditions exist, animals are more apt to suffer from the barn's being too warm than too cold.

General Purpose Barn

Often farmers are found who feed only a few steers over the winter, and these largely for the purpose of obtaining a market for some of their hay and grain, and for the utilization of summer pasture. In addition to the return from marketing the animals, they obtain the fertilizing value for their land of the manure the steers produce throughout the winter. Where only a few steers are kept, it is advisable to build a general purpose barn rather than to attempt to build a separate beef barn, unless the owner contemplates considerable expansion of the enterprise in the near future.

A floor plan of this type of barn is shown in Figure 4. Such an arrangement also makes for greater convenience where small numbers of animals are kept.

Essential Equipment

DEHORNING CHUTE

A dehorning chute of some kind is an almost indispensable piece of equipment on a livestock farm. After one has tried various

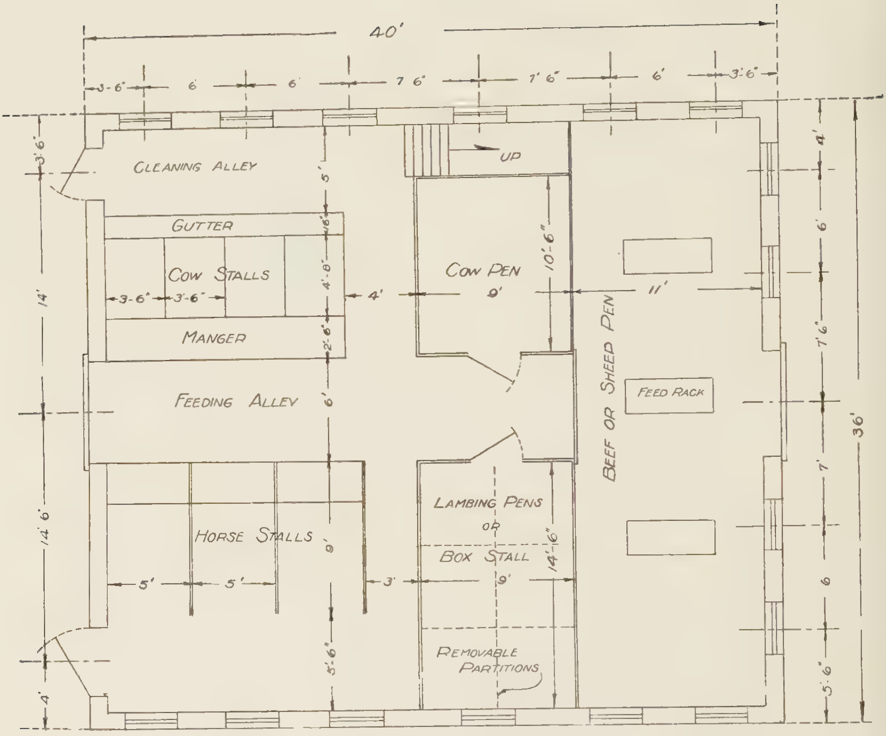


Fig. 4.—General purpose barn designed to accommodate a few beef cattle or sheep in addition to space for housing cows and horses.

make-shift methods of holding an animal for dehorning, he readily appreciates the advantages of a properly constructed dehorning chute.

On all farms where the finishing of beef cattle for market is a major enterprise, there is always more or less dehorning to be done. The advantages of the dehorning chute are that the operation is made much easier, it insures a satisfactory job, and there is little danger of injury to either the animal or the operator when the steer is thus securely held.

The illustration on page 11 shows a satisfactory type of dehorning chute.

CATTLE STOCKS

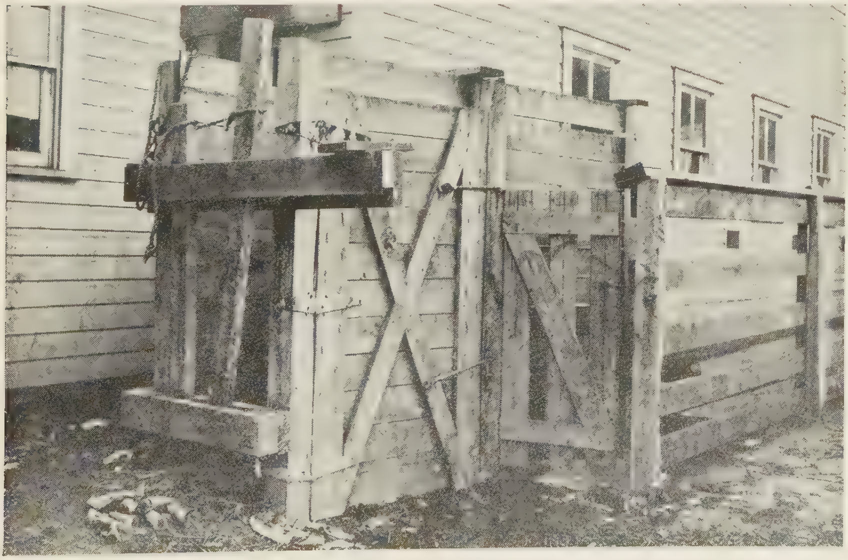
Cattle stocks, such as shown in Figure 5, are a valuable part of the equipment on a livestock farm. There is always danger of injury in throwing an animal for purposes of trimming hoofs, in treating a crippled animal, etc., especially a heavy beef animal. With the stocks

the animal may be handled much more easily and without danger or injury. A heavy canvas sling, attached to the rollers, is passed under the barrel of the animal. With such a device the animal may be lifted from its feet sufficiently to avoid struggling, and treatment can be administered with little difficulty.

HAY RACK

A hay rack in the feed lot is sometimes desirable. This may be easily and quickly constructed as shown in Figure 6. The sills, placed as they are, may be used for skids in moving the rack from place to place. Occasionally a rack of this type is built on low wagon trucks. This latter arrangement makes it possible to fill the rack and locate it with ease. A rack of this type is especially valuable in a dry season when pasture has to be supplemented by other feed, or for winter feeding in the open.

A wall rack for use in the feeding pens may be constructed as shown in Figure 7. This is a combination hay and grain and silage rack. Other satisfactory types of wall racks may be constructed. The one shown is easily constructed, convenient, easily cleaned, and reduces feed waste. These advantages recommend it as a highly desirable type of rack. The doorway "A" may be fastened open and the grain fed with ease.



A dehorning chute is a valuable piece of equipment where beef cattle form a major farm enterprise.

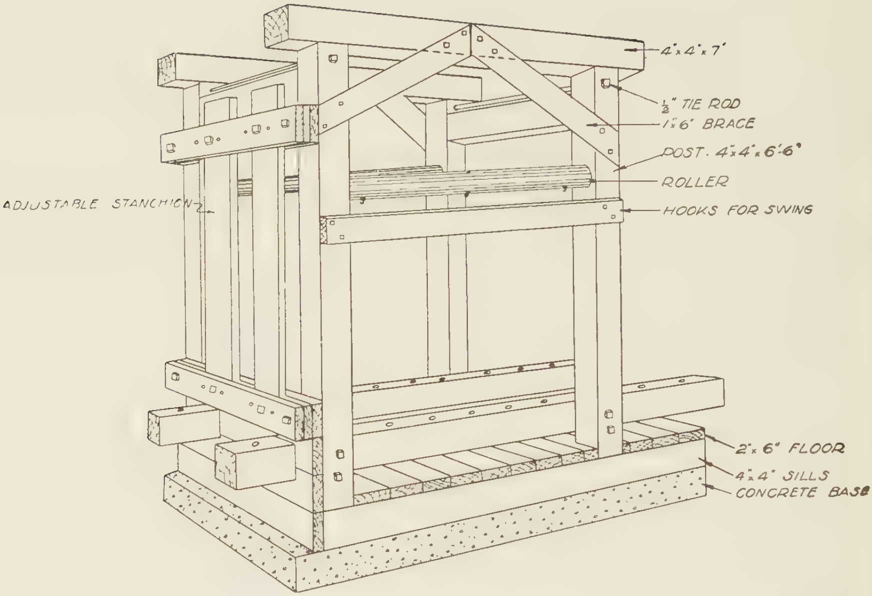
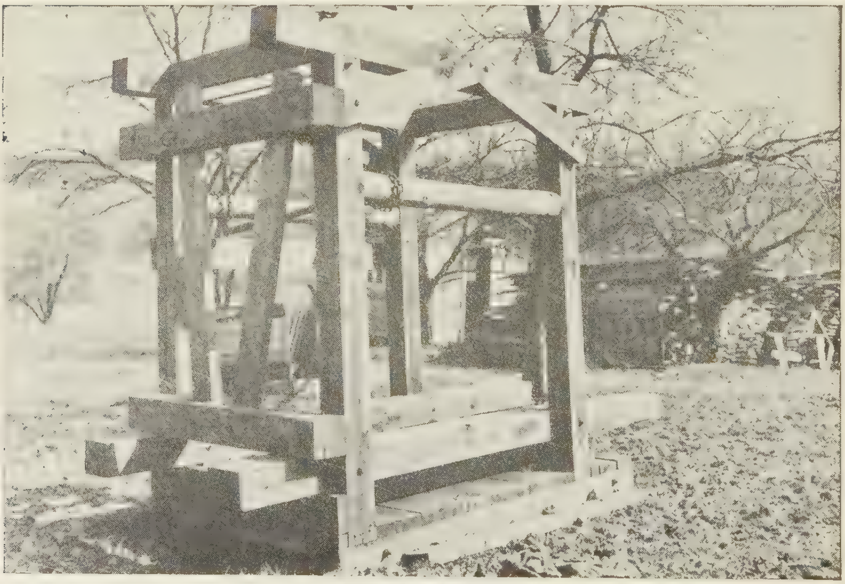


Fig. 5.—Detail of cattle stocks, giving dimensions and plan of construction.



Cattle stocks greatly simplify the handling of beef cattle for various types of treatment.

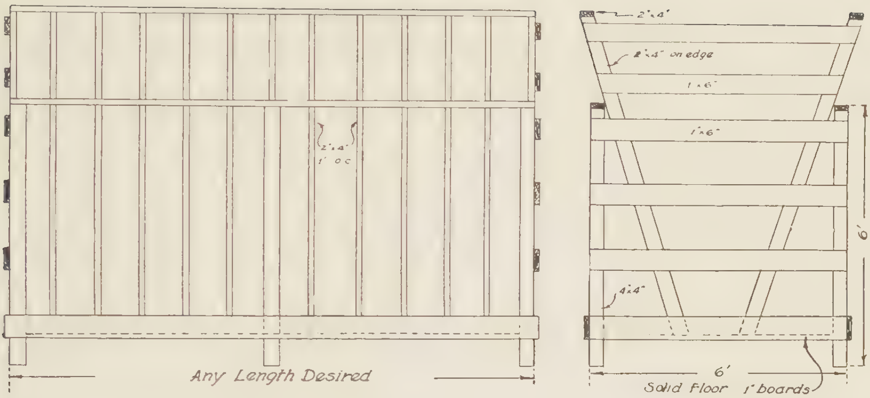


Fig. 6.—Hay rack for field or feed-lot use.

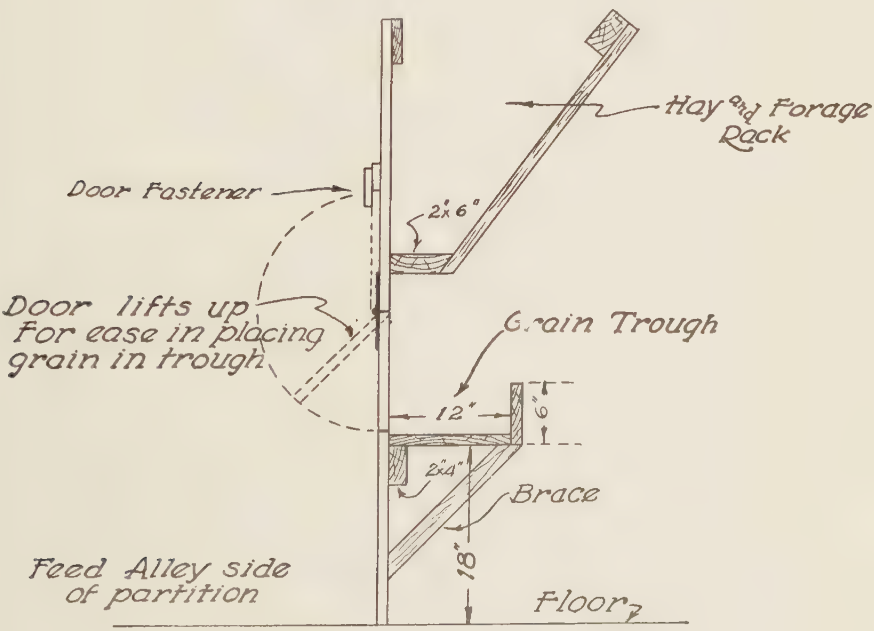


Fig. 7.—Detail of wall rack for use in open shed barns.

DIPPING VAT

The dipping vat shown in Figure 8 is of satisfactory dimensions for beef cattle, if they are not put through the dip too fast. The fact that this vat may be used for cattle, horses, sheep, or hogs makes it

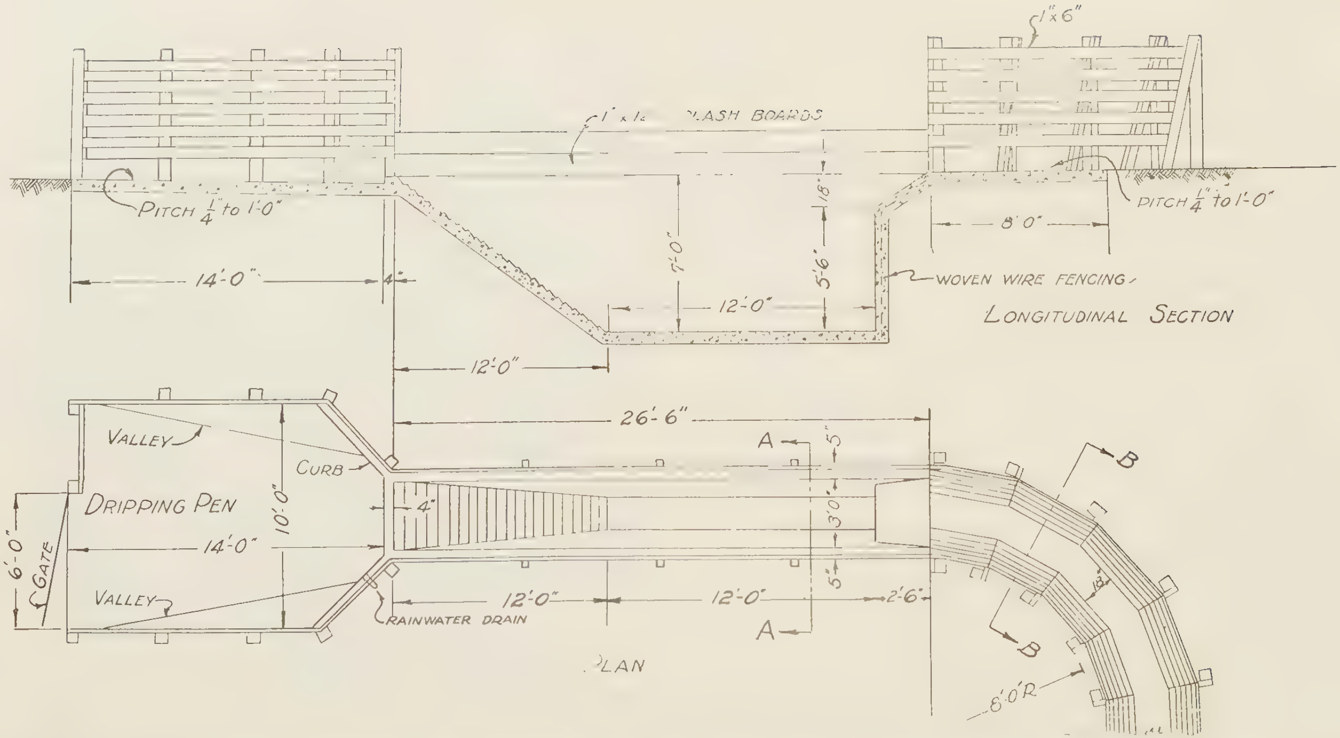


Fig. 8.—Plan of dipping vat for use with cattle, sheep, or hogs. (From plans prepared for use in West Virginia by Portland Cement Association.)

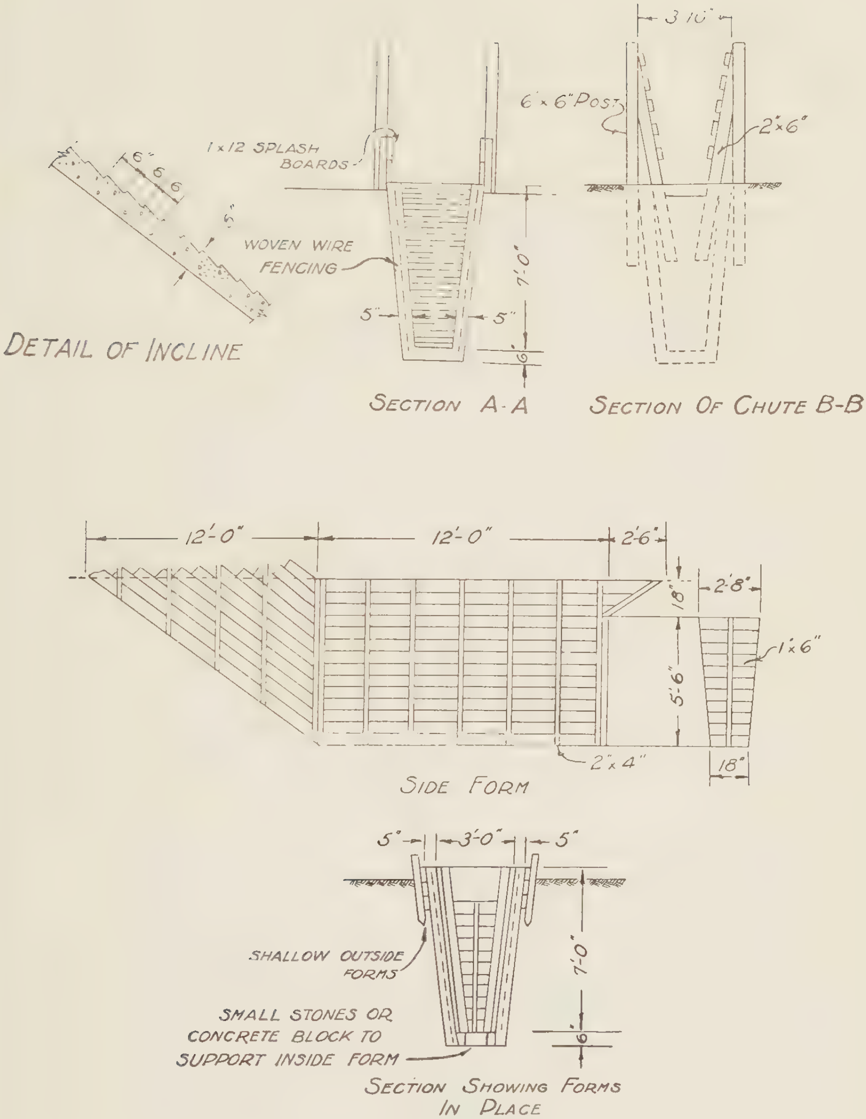


Fig. 9.—Details of dipping vat shown in Figure 8.

valuable equipment on any livestock farm, no matter what the combination of livestock enterprises is. The dipping vat should be located conveniently near and, if possible, below the water supply in order that it may be filled by gravity.

SHIPPING CRATE

Shipping crates for livestock have come into general use since purebred animals have taken such an important place in the livestock industry. Whenever a single animal is to be transported, the crate is commonly used.

Good crates for shipping purposes are as easily constructed as poor ones. It is necessary only to remember and observe a few important points in construction. The crate should be built to fit the animal to be shipped. Bottom boards which are run crosswise give greater strength than boards run lengthwise. Also, top and end slats run crosswise add strength to sheep and hog crates. Due to stanchion construction in cattle crates, verticle slats must be used.

The need for a shipping crate for cattle centers largely around calves, since many are sold individually and are sometimes shipped long distances.

Figure 10 shows a type of shipping crate for calves that is strong and serviceable. This same crate may also be used for sheep and hogs. It should be built to fit the animal to be shipped.

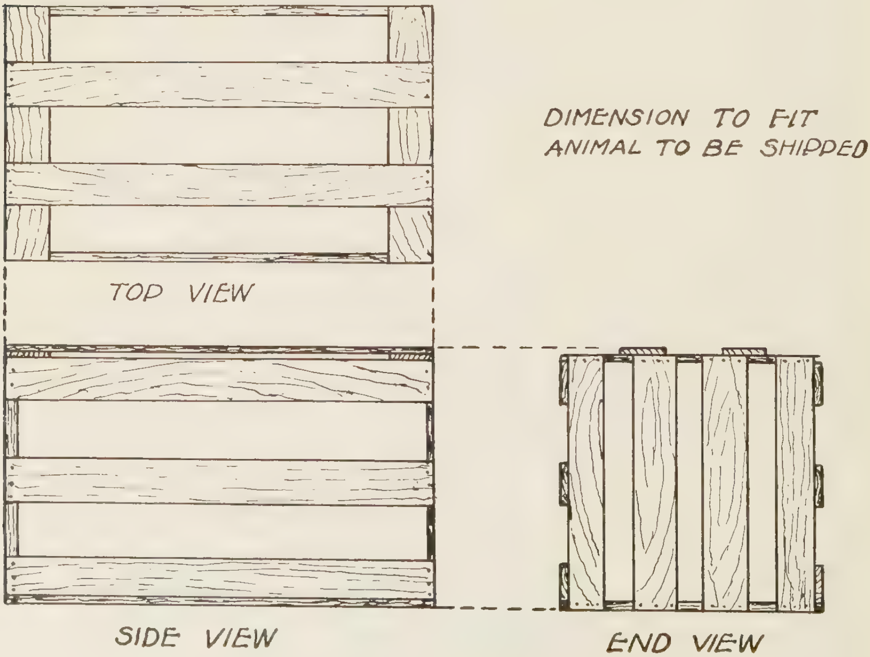


Fig. 10.—A shipping crate for calves, sheep, or hogs.

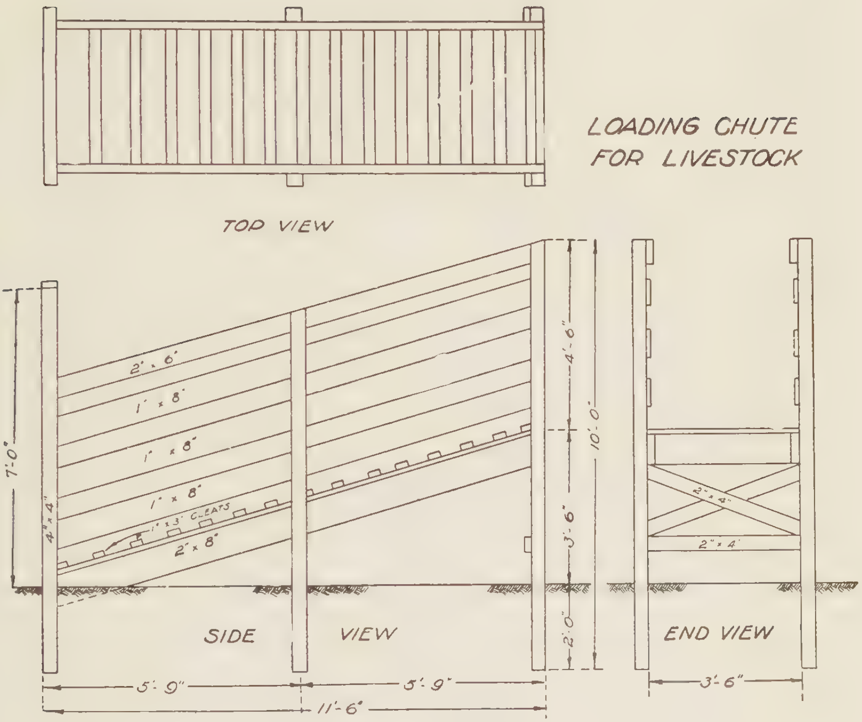


Fig. 11.—Plan for construction of a loading chute for livestock.

LOADING CHUTE

Since so much of the transporting of livestock is now done by truck, there is a real need for a loading chute.

Figure 11 shows a loading chute with posts set in the ground. If desired, the posts might be set on runners, thus making it possible to move the chute to any favorable location. Or a pair of wheels could be attached slightly to one side of the center of the chute, so that by lifting the heavier end of the chute (the end resting on the ground) the whole rack might be moved on the wheels with little difficulty. When in use, one end of this rack would rest on the truck or wagon, with the other end on the ground, and supported by the wheels in the center.

FARM GATE

On any livestock farm the matter of fencing and good gates is an important consideration. The percentage of strong, sound, non-sagging gates to be seen as one travels through a farming community

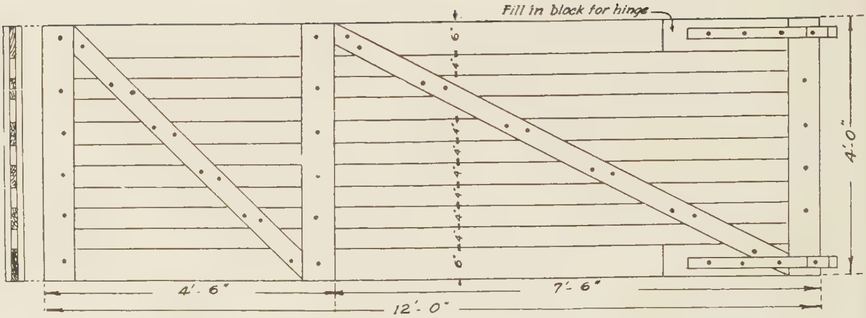


Fig. 12.—Plan showing easy method of constructing a satisfactory farm gate.

is surprisingly low. A little time spent in properly constructing a gate and in properly setting the gate posts would save many farmers great deal of time, remove the cause for outbursts of temper, and give a more pleasing appearance to the farm.

Figure 12 shows how a good farm gate may be constructed. If the gate post is properly braced and set, the gate will not sag.

Concrete watering troughs may be cheaply and easily constructed, and are a valuable asset to the farm.

WATERING TROUGH

For best results with beef cattle, water should be readily available at all times, preferably near the feed racks. For this reason it is often advisable to locate a watering trough near the feeding shed.

A concrete trough is probably preferable and it should be set on the concrete pavement of the court outside the sheds. This avoids a mud hole around the trough and makes the water easily accessible.

Figure 13 shows the method of constructing a concrete watering trough. A rich mixture, well spaded in the forms, is necessary if the trough is to be watertight. A 1-2-3 mixture (one part of cement, to two parts of sand, and three parts of gravel) is satisfactory for work of this type. The concrete should be put in the forms in one continuous operation to prevent cracks and leaks.

For reinforcing on small tanks, wire mesh is satisfactory. For larger tanks both verticle and horizontal reinforcing should be used.

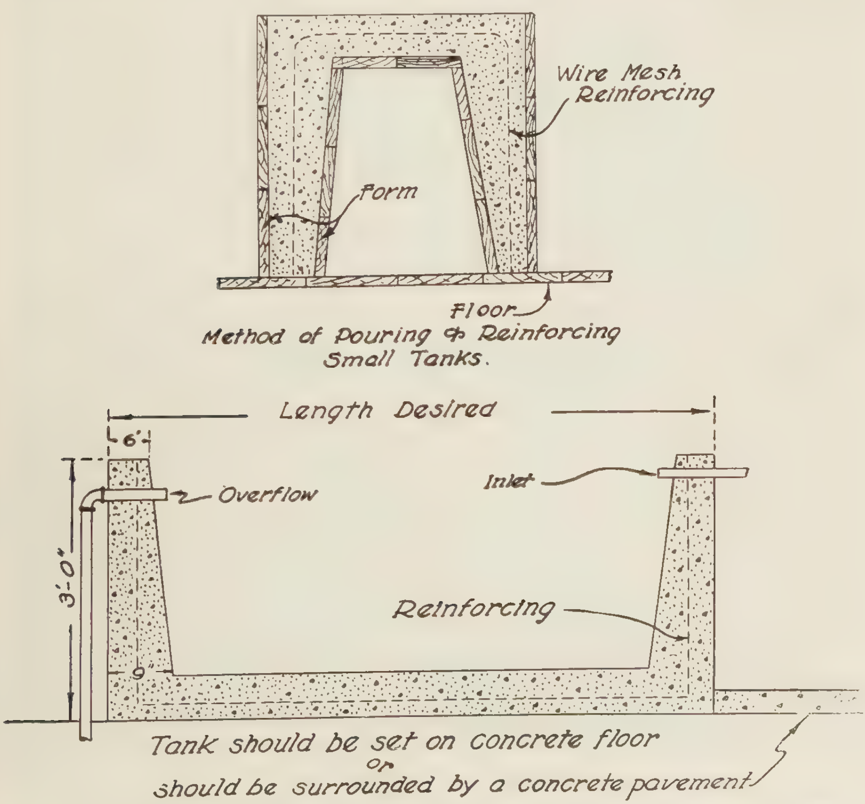


Fig. 13.—Details of method of constructing forms and pouring a concrete trough.

(Photo, Courtesy J. V. Ankeney.)

Sheep are found on an increasingly large number of farms in West Virginia.

BUILDINGS AND EQUIPMENT FOR SHEEP

For several years West Virginia farmers have been receiving favorable prices for lambs and wool, in spite of the severe depression in general farm prices. This has been due to several factors, among which are the nearness to the Pittsburgh, Baltimore, and Jersey City markets, the improved quality of the lambs and wool marketed, and an increasing demand on these markets for West Virginia high-quality lambs.

As a consequence, the sheep industry in West Virginia has been and still is growing, as is indicated by an increase of 65,000 head, on January 1, 1928, over the 1927 figure for the state. For the reasons mentioned, and the fact that West Virginia has an abundance of bluegrass pasture and favorable climatic conditions, the sheep industry will undoubtedly continue to rank as an important agricultural enterprise in the state for some time to come.

Farmers are realizing, however, that to produce the quality of lambs and wool demanded by the markets, and to maintain the health and vigor of the flock, a definite amount of care and protection is necessary. Although little in the way of expensive equipment is needed for successful sheep raising, a certain amount of equipment for definite purposes is essential.

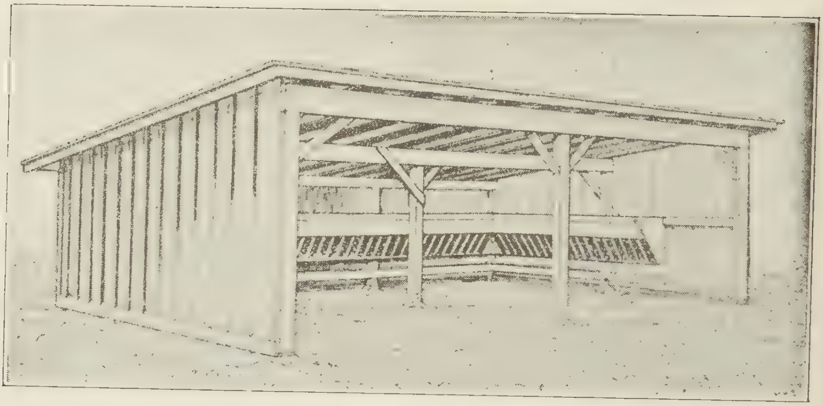
"Poor equipment and management, though easily remedied, are responsible for discouragement and loss in sheep raising. Little or no shelter is provided the flock in winter with very little or no feed other than pasture, and as a result the owner shears a light, weak-fibered fleece, and has emaciated ewes that are too thin to properly suckle their lambs. Without a pen of some kind it is very difficult to catch sheep, and as a rule in case a suitable pen is not provided, docking and castrating of lambs are not performed, ewes are not kept tagged, and treatment for parasites is not attempted."*

The Sheep Shed

ESSENTIALS OF CONSTRUCTION

The sheep shed or barn need not be an elaborate structure under any conditions. If it combines the essential features of adequate protection from the cold rains of early fall, winter snows, and other unfavorable climatic conditions, and is dry, light, well ventilated, and has sufficient space to prevent crowding, the type of building is of minor importance.

*West Virginia Agricultural Experiment Station Circular 48.



An open front sheep shed satisfactory for shelter and feeding.

Sheep do not require a building that it particularly tight. A single wall construction is sufficient to meet all their requirements. Shade and protection from intense heat are, however, of particular importance during hot summer weather. If at other times the flock is adequately protected from drafts, and is in a dry place, that is all the shelter that is necessary with the exception of some special protection at lambing time.

The sheep shed should always be well ventilated. In fact, occasions are few when sheep have to be shut in. In West Virginia, the ventilation openings such as doors and windows may be left open practically all of the time. No automatic system of ventilation is needed.

Sheep should never be crowded into cramped quarters. In planning the sheep shelter, a minimum of ten to twelve square feet of floor space should be allowed per head. This prevents crowding, possible injury, and helps to maintain the health and vigor of the flock.

FOUNDATION AND FLOOR

It is not necessary that a solid concrete wall foundation be built for a sheep shed. The shed may be supported very satisfactorily and much more cheaply on concrete piers, with provision for anchoring the posts as shown in Figure 14. Vertical siding with stripping may be nailed to stringers run between the posts as shown in Figure 15. The shed may be made sufficiently tight at the bottom by banking with plenty of loose straw litter.

The floor should not be of concrete as this is an unnecessary expense. A good clay floor becomes tightly packed after the shed has been in use for a time, and will remain dry, if it is slightly above the grade level outside and the site is properly drained. A clay floor, kept well bedded, is the best floor for sheep. The litter soon becomes tightly packed down, and all that is necessary in cleaning is to take out everything to the dirt and add a liberal supply of new bedding.

LOCATION

The sheep shed should be located on a well-drained site. If the natural drainage is poor, sub-surface drains should be installed before construction is begun. For good drainage, a loose sandy soil is to be preferred. A location on a slope with a southern exposure is desirable where possible.

The location of the building should be chosen with the view to obtaining the greatest convenience in caring for the flock. It should be adjacent to or conveniently near pasture or forage areas, and as near the other buildings as is feasible, in order to obtain a farmstead layout that makes for the greatest economy of time and labor.

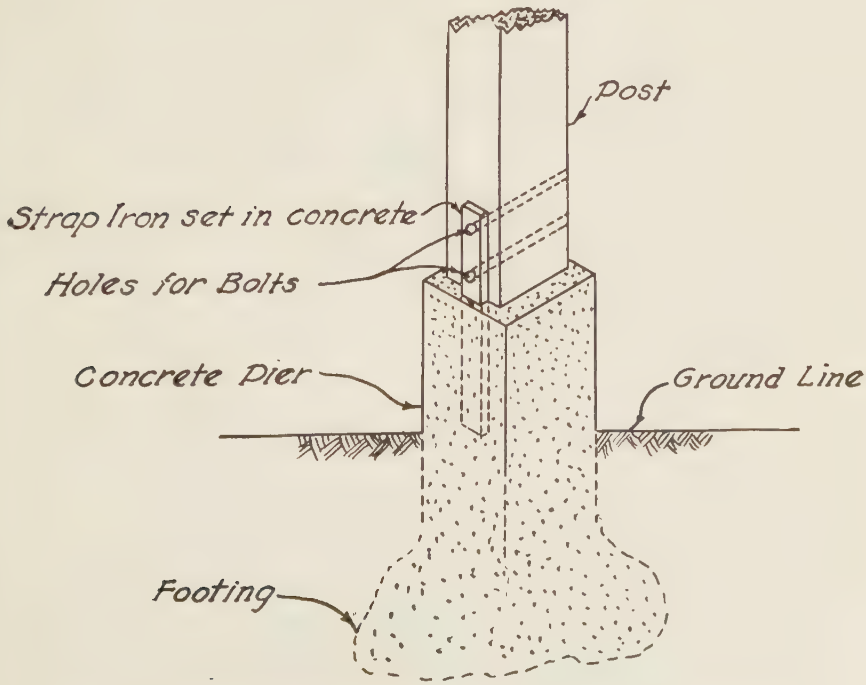


Fig. 14.—Detail of supporting and anchoring posts in sheep shed construction.

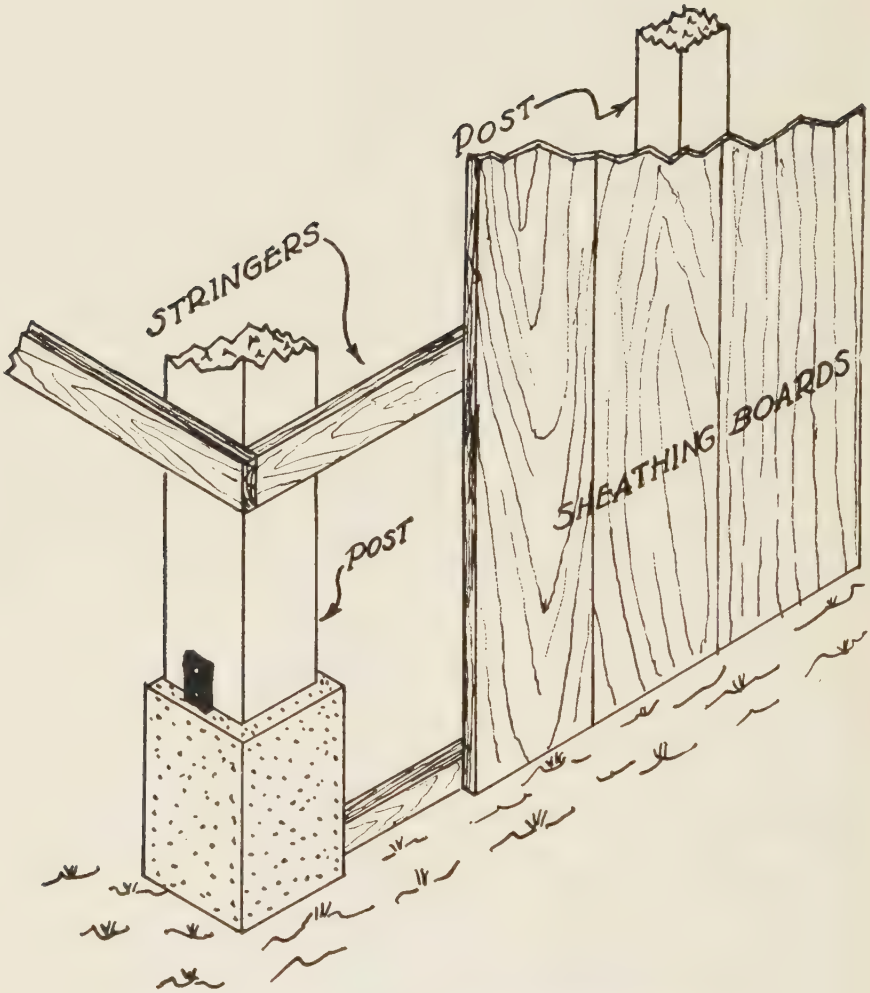


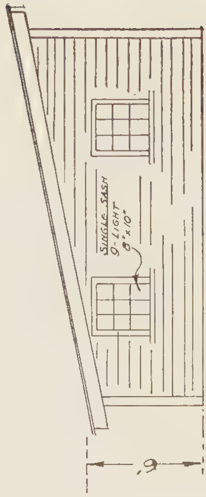
Fig. 15.—Method of placing siding on sheep shed.

PLANS FOR SHEEP SHEDS

Keeping in mind the essential and desirable features of sheep shed design, attention is called to the plans of sheep sheds shown in Figures 16 and 17. These sheds were designed using the same floor plan, the main difference being in the provision for storage in the two-story barn. The buildings as shown will accommodate 60 sheep, and the arrangement of feed racks indicated provides ample rack space,

allowing one and one-half feet per animal. The dimensions of the building may be varied according to the capacity desired.

It will be noted that slatted doors are used. This is to allow for plenty of air circulation. Tight doors are unnecessary, and are undesirable on most sheds, under West Virginia conditions. The sliding doors prevent blowing and flapping by the wind, and they are easier to control single-handed than the large swing doors. The danger of sagging is also eliminated.



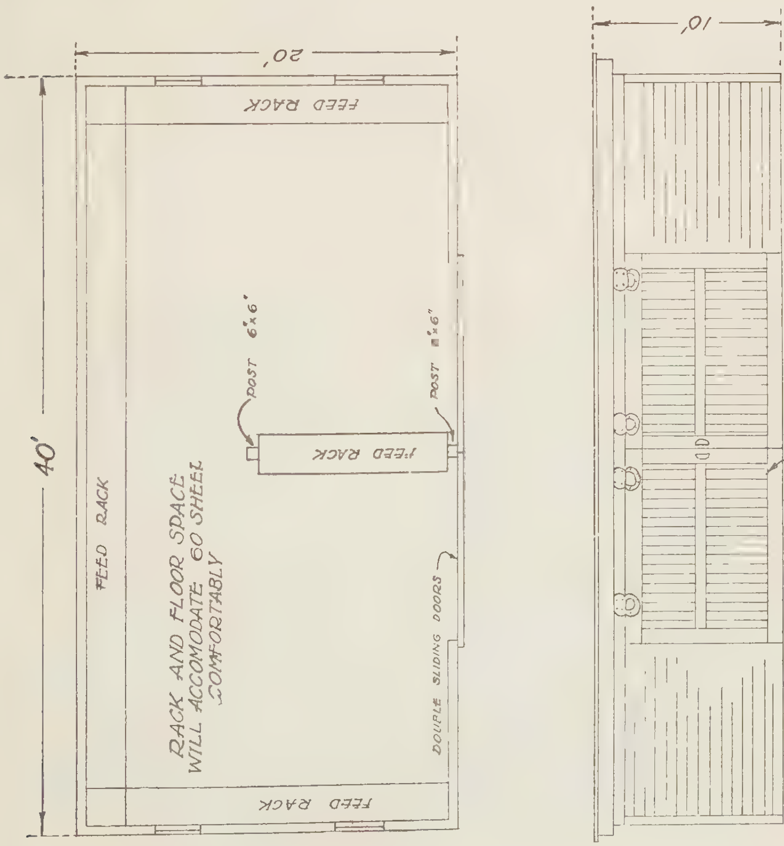


Fig. 16.—Plan of sheep shed without storage.

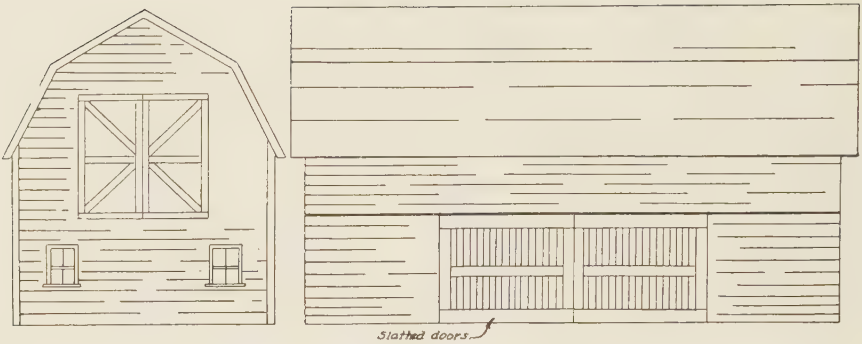
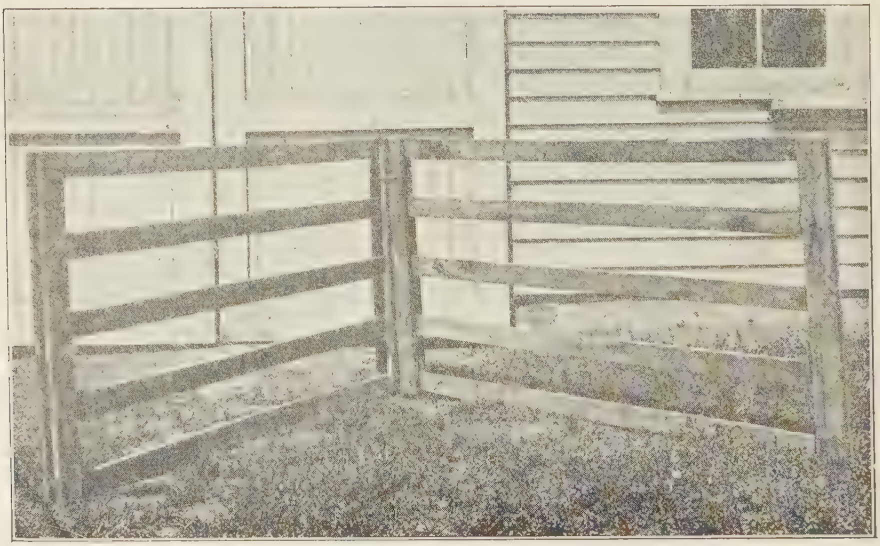


Fig. 17.—Same plan as in Figure 16 with storage space added.

The windows are placed in the shed to provide added light and ventilation. They are hinged at the bottom and should be left open practically all of the time. This method of placing the windows makes it possible to obtain the desired ventilation without causing direct drafts. Figure 3 on page 9 shows the window detail.

Figure 4 on page 10 shows how provision for sheep shelter might be included in the construction of a small general barn.



Panels of this type are convenient for erecting temporary lambing pens.

Desirable Equipment*

TEMPORARY SHEEP PEN

The panels for setting up a temporary sheep enclosure, as shown in Figure 18, are a valuable part of the sheep owner's equipment. With these panels a treating chute or pen may be quickly and easily set up. Since sheep probably suffer more from parasites than any other class of livestock, it is essential that they be treated regularly. Where provision for such treatment is lacking it is often neglected, resulting in losses in the flock, lowered vitality, weak-fibered fleeces, and lower market prices.

Advantages of the type of enclosure shown are the ease with which the panels may be constructed, the adaptability of the panels for various uses, the speed and ease with which they may be transported and set up, and the fact that the pen or chute may be set up wherever most convenient.

LAMBING PEN PANELS

Panels such as shown in the illustration on page 26 prove to be the cheapest and handiest method of constructing temporary lambing pens. These panels are 30 inches high and can be set up quickly and with little effort. When not in use they may be stored away, taking little storage space.

FEED RACKS FOR ROUGHAGE

Feed racks should be so constructed that hay, chaff, and dirt cannot fall into the sheep's wool. The rack in Figure 19 has been found very satisfactory in feeding roughage to sheep, and is easily constructed. The keeping of dirt and chaff out of the wool prevents irritation, and is important, too, when one realizes that burry and seedy wool brings from five to ten cents per pound less on the market. Good feed racks also save labor and conserve feed.

The racks may be built in units as shown or may be modified into a continuous wall rack. In building a 12-foot unit of the rack shown in the figure the following materials will be needed:

10	pieces	1"x6"x12'
1	piece	2"x6x"x12'
40	pieces	1"x3"x2'-"
2	pieces	1"x6"x30"
2	pieces	1"x8"x30"
2	pieces	1"x3"x30"
10	pieces	1"x6"x36"

*For details of construction of dipping vat see Figure 8, page 14. Directions and formulae for dipping sheep may be found in West Virginia Agricultural Experiment Station Circular 48, a copy of which is available upon request.

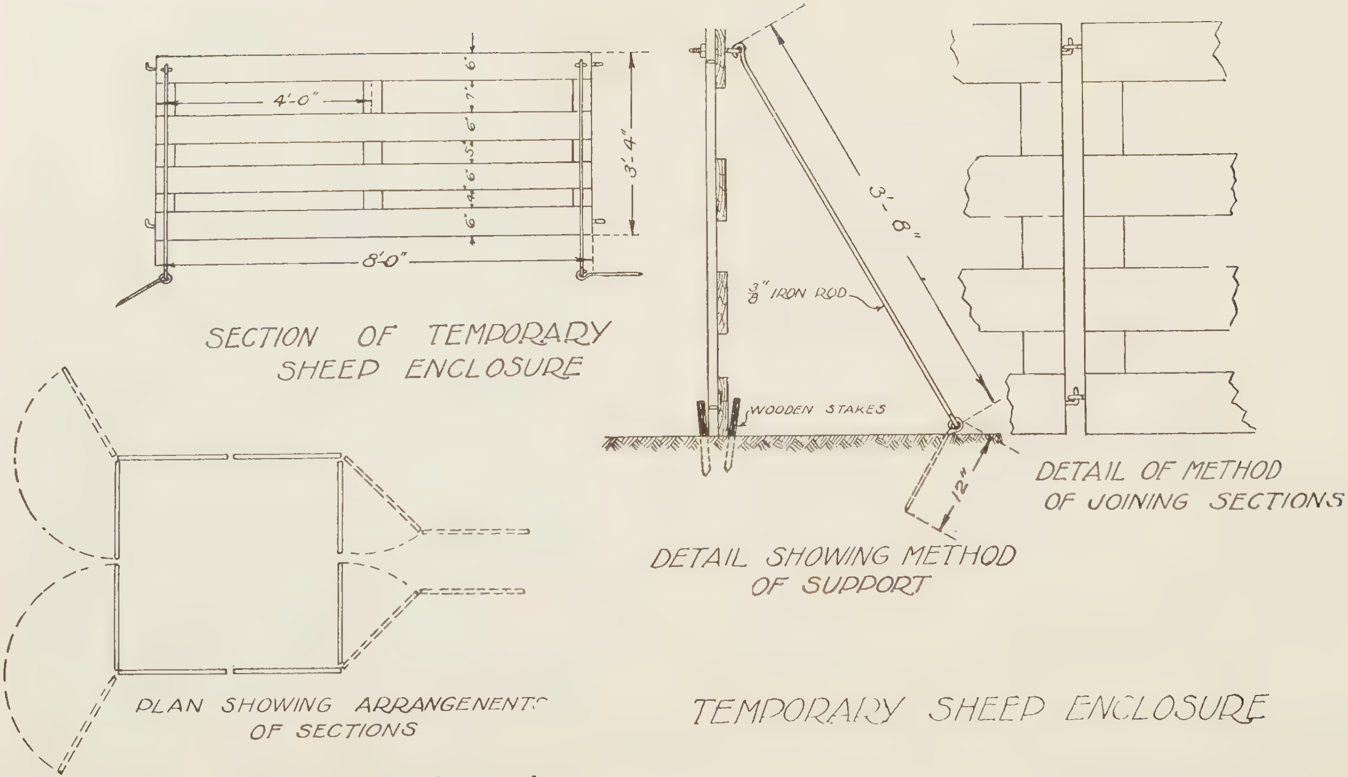


Fig. 18.—Details of temporary sheep panels.

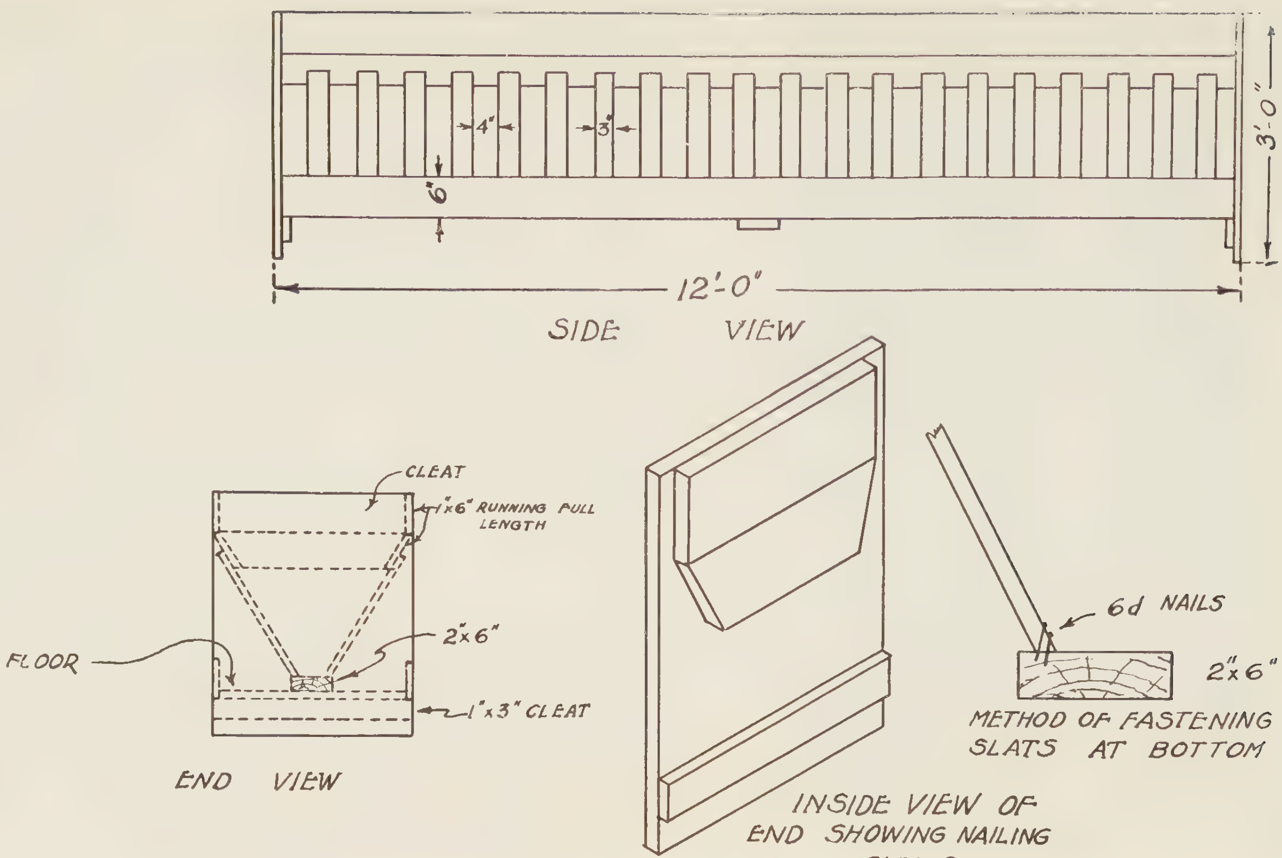
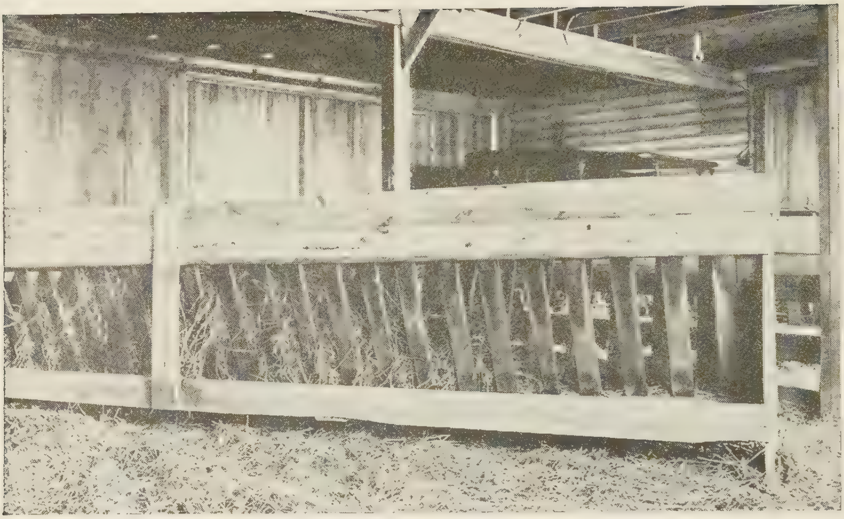


Fig. 19.—Plan of hay rack for sheep.



Sheep forage racks save labor, conserve feed, and protect the wool from dirt and chaff.

GRAIN TROUGHS

A grain trough such as is illustrated in Figure 20 is of value in sheep feeding. The trough may be moved from place to place, is easily constructed, and the reversible feature greatly facilitates cleaning. The trough is especially valuable where sheep are to be fed out of doors. Such a trough may be permanently located, if preferred, by placing a post in the ground as a support at either end of the trough.

LAMB CREEPS

In raising lambs it is often desirable to feed them some grain. In order to do this, some device for admitting the lambs and excluding the old sheep is necessary. The lamb creep serves this purpose, and it may be of a variety of designs. One that has proved satisfactory is shown in Figure 21. The openings allow for the ready passage of lambs back and forth but prevent the larger sheep from following.

THE SHIPPING CRATE

The general principles of construction of shipping crates described on page 6 apply to the case of the sheep crate.

In the sheep crate it is important that enough head room be allowed the animal, that it may stand naturally and comfortably, rather than have its neck in a cramped position. The illustration on page 32 shows a satisfactory shipping crate construction. A strip of

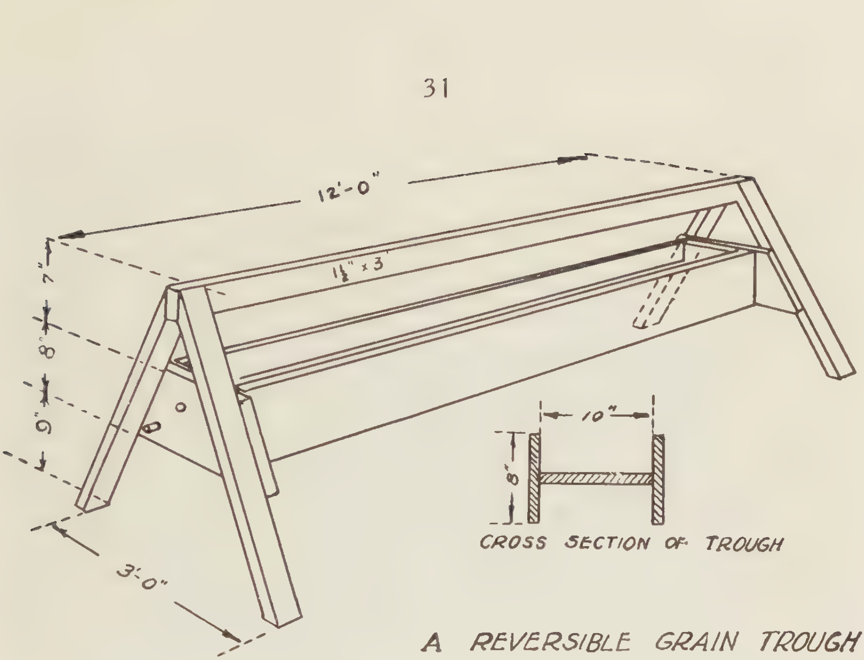


Fig. 20.—Grain trough for use in feeding sheep.

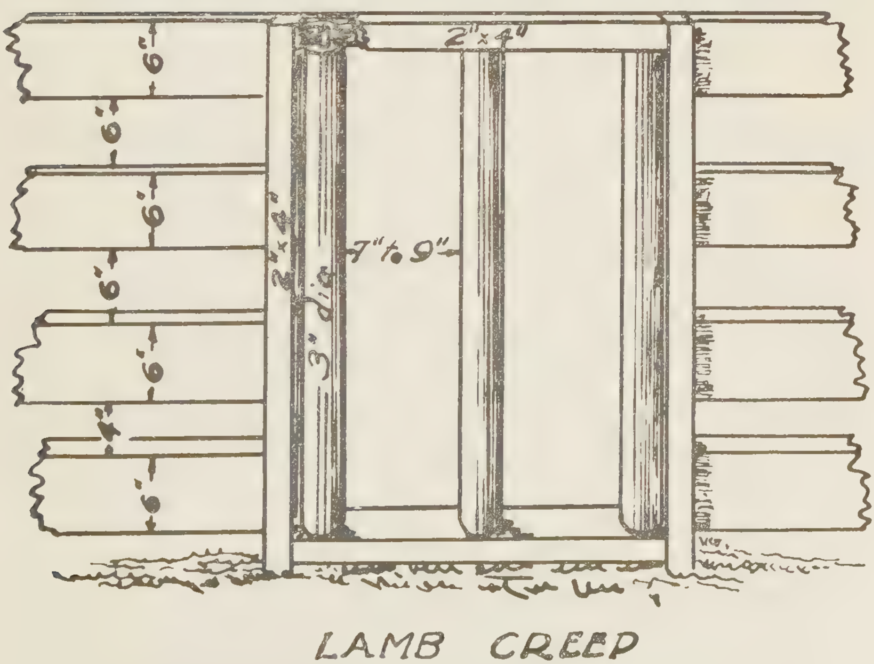
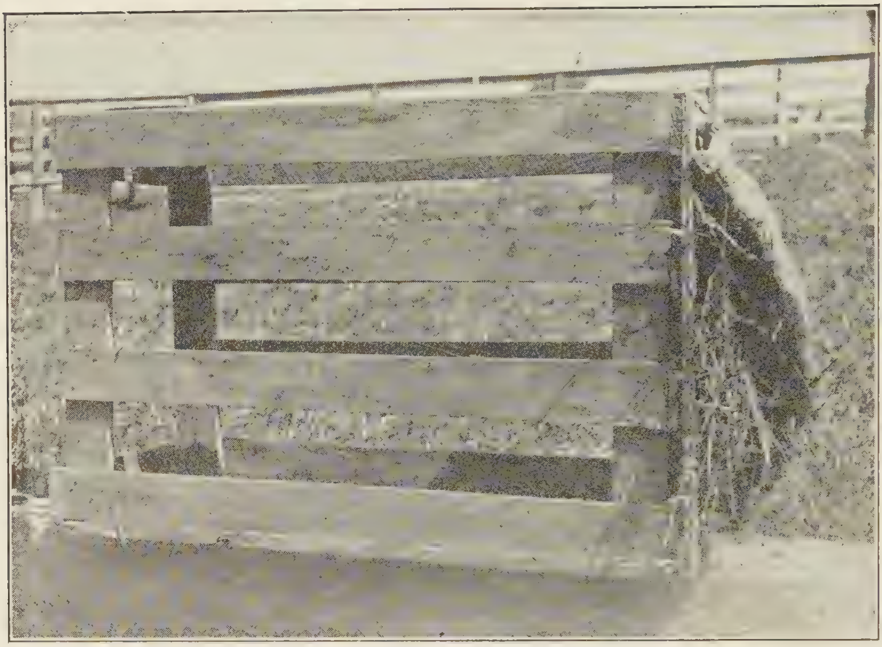


Fig. 21.—One method of constructing a lamb creep.



A satisfactory type of sheep shipping crate. Note the provision for feed.

burlap over the top of the crate is of aid in preventing travellers and handlers from poking and annoying the animals in transit.

SALT BLOCK

One of the parasites which causes trouble among sheep is grub in the head. This is brought about by the depositing of the larvae of a fly on the nose of the sheep. These larvae travel up the nostrils and set up a serious irritation in the membranes of the head cavities. The result of this infestation is weakness, loss of flesh, and sometimes death.

One means for controlling this parasite is by the use of a salt block or lick log. This is merely a log or timber with several two-inch holes bored in it. Salt is placed in the holes and the back edges of the holes are smeared with tar. The sheep, in getting the salt, get the tar on their noses, which serves as a repellant for the flies. Placing the log so the sheep can get at it from only one side prevents them from getting tar smeared on the lower jaw. Small pieces of felt may be tacked in the back sides of the holes to hold the tar.

WOOL-TYING BOX

The wool-tying box shown in Figure 22 is a handy piece of equipment in preparing wool for the market. The advantages offered for its use are the ease and uniformity with which the fleeces may be tied, and their more attractive appearance from the market viewpoint when tied in this way.

The box is simple, easily constructed, and the cost negligible as compared with its value in preparing a neatly well-tied fleece for the market.

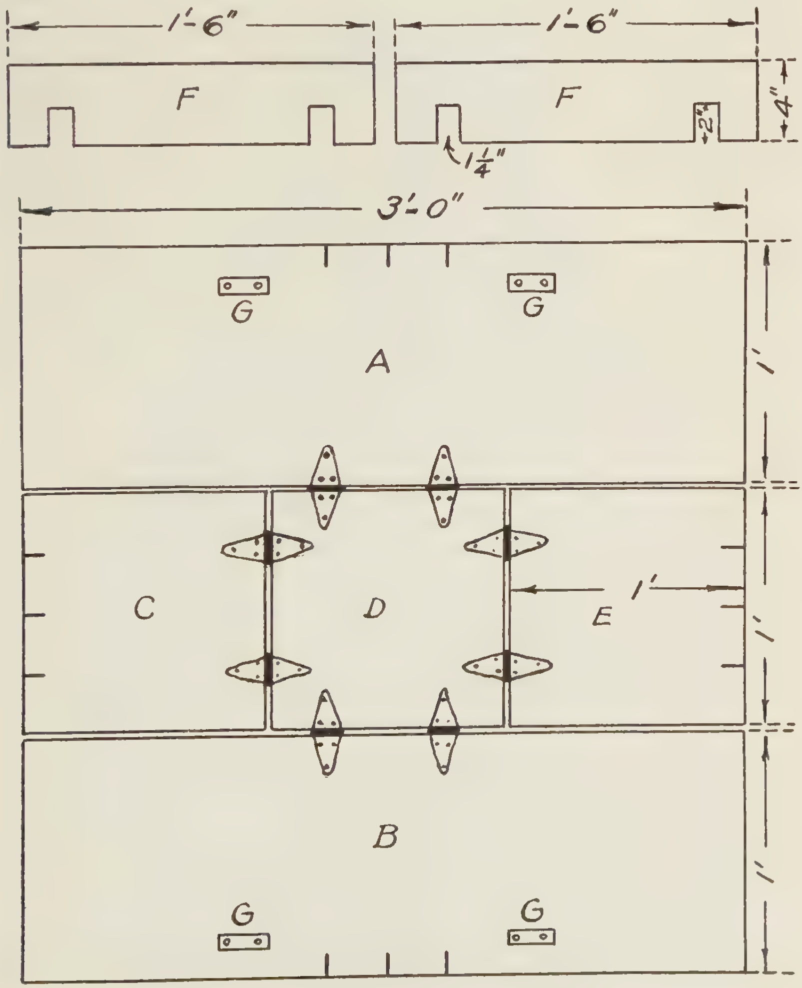


Fig. 22.—Detailed directions for making wool-tying box.

Returns from the enterprise with hogs depend on proper housing, feeding, and care.

BUILDINGS AND EQUIPMENT FOR HOGS

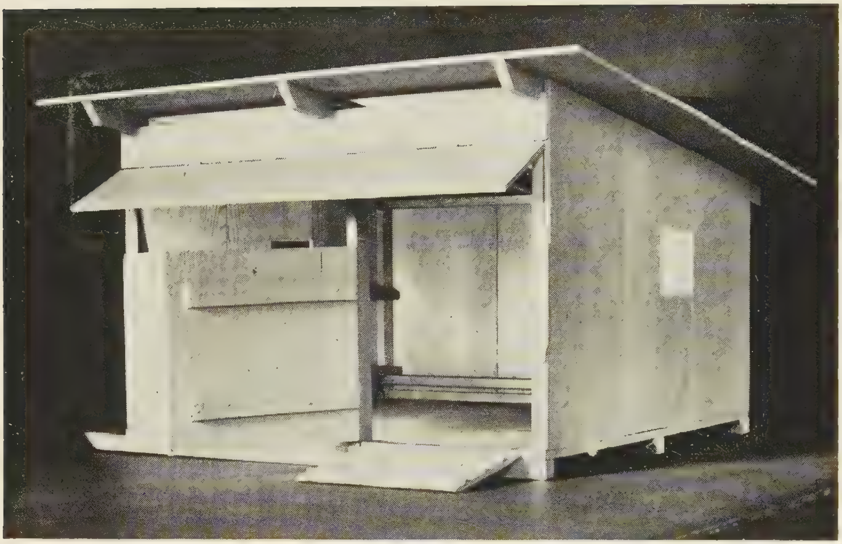
The production of pork for home use will probably always be an item in the farm business. In spite of the fact that the greatest amount of pork for commercial purposes is produced in more or less defined areas, farmers in West Virginia are taking a much keener interest in this phase of farming than formerly, as indicated by an estimated hog population of 240,000 for the state, January 1, 1928. Housing conditions, feeding methods, breeding practices, and the quality of animals kept, have all been improved. This has undoubtedly been greatly stimulated by Four-H club projects, the ton litter movement, market demands, and other factors. There is still much work to be done, however, particularly in the matter of housing. This was clearly shown by the results of a preliminary survey of farm sanitary conditions made on 215 farms in West Virginia during the summer of 1923. Notes were taken on all of the farm buildings, and of these, the hog houses ranked lowest in every respect, including cleanliness, construction, design, and appearance.

The idea that the hog is by nature a filthy animal, and that it will thrive under very adverse sanitary housing and feeding conditions must be dispelled. McLean County, Illinois, in cooperation with the United State Bureau of Animal Industry, has developed a plan of sanitary swine management which has been tried by hundreds of farmers in the West and South. The results have convinced these farmers that swine management on a sanitary basis is both successful and profitable.

Proper housing conditions are of primary importance in obtaining desired sanitary conditions. The value of housing and equipment in obtaining healthy animals, efficient utilization of feeds, in preventing the spread of parasites and disease, and in lowering mortality in young pigs can hardly be over-estimated. With many farmers, the difficulty seems to be a question as to what type of house to build, how to build it, and what equipment is practical and valuable. The following plans and discussions should aid in solving this problem.

The Hog House

There are two general types of hog houses—the individual or colony house, and the larger community or central house. Each possesses several advantages, but for the farmer who keeps only a few hogs, as is the case on most farms in West Virginia, the colony unit is more practical and economical. A method whereby a combination may be made to result in what is practically a community plant is described later.



The West Virginia type farrowing house. Note the guard rails inside.

ESSENTIALS IN HOG HOUSE CONSTRUCTION

There are a few essentials to be considered in planning a hog house. These are: proper sanitation; warmth in winter; coolness in summer; proper ventilation; adequate light, especially direct sunlight; dryness; economy in construction; durability; and neat apparance.

Proper sanitation includes such features as plenty of sunlight, proper ventilation, warmth, and dryness. A well-drained floor and site are important in maintaining sanitary conditions.

Hogs are more or less sensitive to extremes of heat and cold, and, consequently, need a warm house in winter and a cool one in summer. Pigs must always be warm and dry. In fact, all classes of hogs must be housed comfortable if the best results are to be obtained.

LOCATION

The location of the colony house may be changed from time to time since the house is easily moved. The West Virginia type house should face the south, however, to get the maximum amount of direct sunlight.

The community house should always be located on a well-drained site and in such a way as to get the maximum amount of sunlight in the house during the day. This latter point is governed somewhat by the type of roof and the arrangement of windows and skylights.

ADVANTAGES OF THE COLONY HOUSE

The advantages of the colony house may be enumerated as follows:

1.—Different rations are fed pregnant sows and fattening hogs. Colony houses make it possible to separate them effectively.

2.—Brood sows demand plenty of exercise. Fattening hogs make more economical gains if somewhat restricted.

3.—Sows may be free from disturbance when farrowing.

4.—The spread of disease is more easily controlled.

5.—The location of the house may be changed at any time when the surroundings become unsanitary.

6.—Each litter is reared by itself and is free from disturbance.

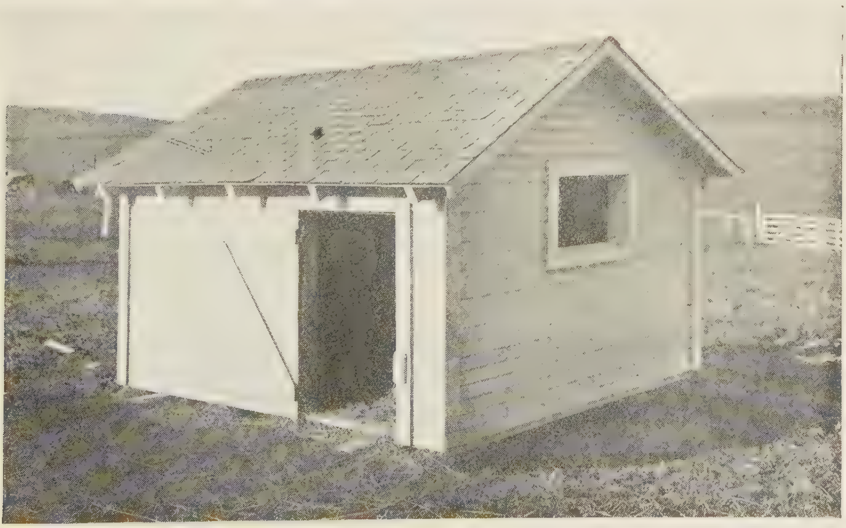
7.—For the farmer with only a few hogs, this type of house is by far the more economical.

ADVANTAGES OF THE COMMUNITY HOUSE

1.—There is an economy of time and labor in caring for the hogs housed in this way. This makes for greater convenience, also.

2.—This type of house is warmer, due to the type of construction.

3.—The central hog house is of more permanent construction and more pleasing appearance.



A type of colony hog house commonly in use.

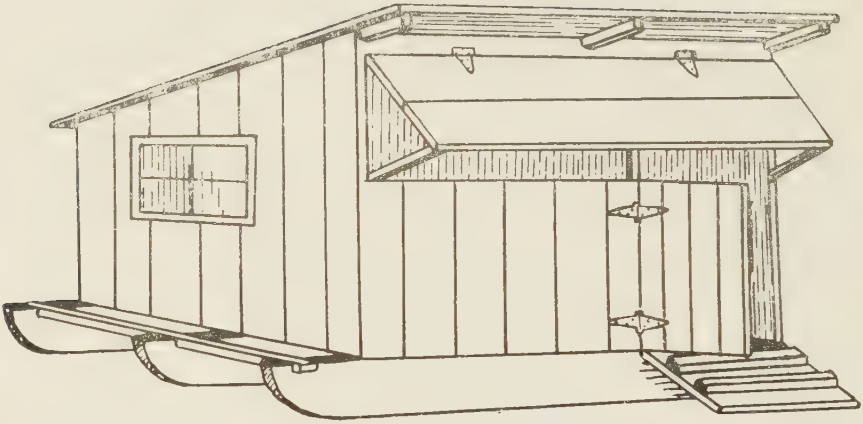


Fig. 23.—The West Virginia type farrowing house.

4.—A central hog house with concrete or masonry walls and floors is more easily kept clean.

5.—Two litters per year can be raised without heavy losses.

6.—This type of house saves fencing.

7.—Artificial heat may be used in this type of building when deemed advisable.

THE WEST VIRGINIA FARROWING HOUSE

For general utility, either for farrowing purposes, or for housing small numbers of fattening hogs, the house shown in Figure 23 has

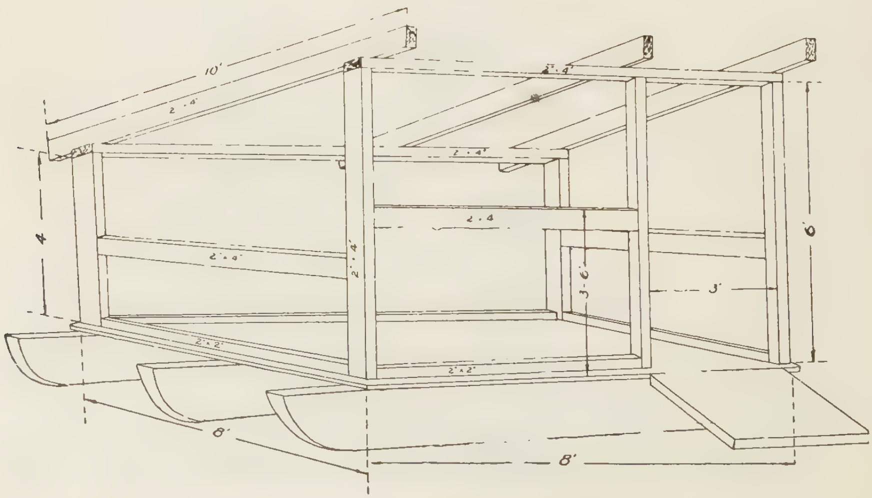


Fig. 24.—Framing construction of the West Virginia type house.

been found very satisfactory. Numbers of these houses are now in use throughout the state, and since on most West Virginia farms only a few hogs are kept, the houses are well adapted to existing conditions.

The generally accepted dimensions for a hog pen are 6 by 8, or 8 by 8 feet. It will be noted that the West Virginia house is 8 by 8 feet, providing ample room. The large hinged door at the front may be raised any desired distance, thus providing ventilation and light. The windows on either end of the building also function in allowing light and air to enter as desired.

The framing and construction is very simple, as can be seen from Figure 24. For skids, hewed poles of ample size are probably most satisfactory. The house may be readily entered, is easily kept clean, is warm under West Virginia climatic conditions, and if properly constructed and cared for, is dry. The cost is not prohibitive, the building is neat in appearance, and if properly maintained, will last indefinitely.

Another type of colony house is shown in the illustration on page 37. This is a gable roof house with much the same details as found in the West Virginia type. In some colony houses of this type, windows are placed in the roof, thus allowing direct sunlight to flood the pen when the window covers are raised.

When the pen is to be used for farrowing purposes, it should always be equipped with guard rails or fenders. This is to prevent the little pigs from being crushed. These rails may be made of wood or pipe. A 2 by 4 inch piece makes a good fender. These guard rails should be 6 to 8 inches above the floor and should extend 6 to 8 inches into the pen. A good support for the rail may be made from a piece of 2 by 8 or 2 by 10 inch material notched to receive the rail as shown in Figure 25. These supports may be scattered at intervals along the length of the rail. Such rails must be substantially supported and securely fastened down or the hog will soon root them out of place.

The following is a bill of materials necessary for the construction of a West Virginia type farrowing house:

BILL OF MATERIALS

3 pieces 4″x4″x9′ for runners. (It is recommended that Chestnut or Locust poles be cut and roughly blocked out and used for runners.)

128 ft. of 2″ flooring—8 feet long (1½″ flooring may be used)

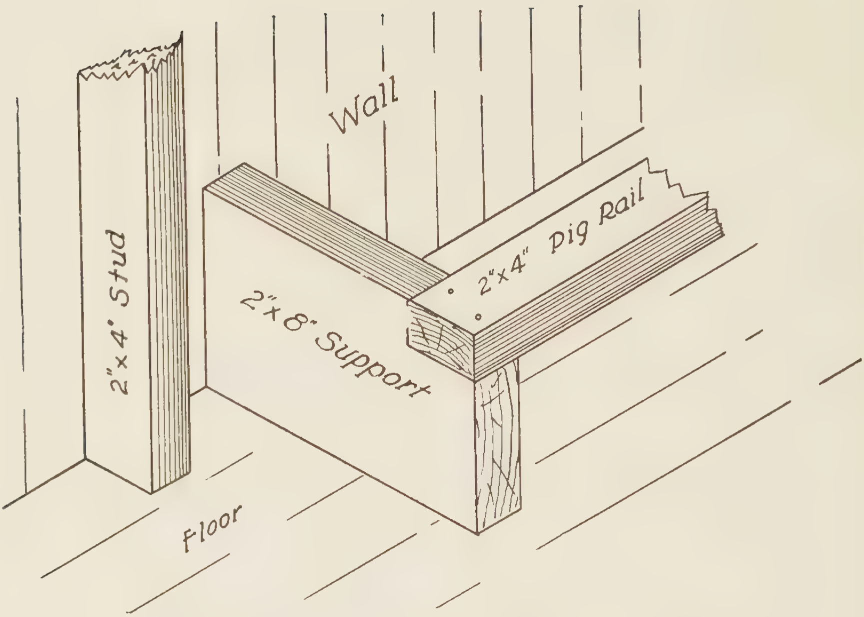


Fig. 25.—Detail of one method of supporting guard rails.

3 pieces 2″x4″x6′ for front studding
3 pieces 2″x4″x4′ for rear studding
2 pieces 2″x4″x8′ for top plates
3 pieces 2″x4″10′ for rafters
4 pieces 2″x2″x8′ for floor plates (To nail the siding to)
96 ft. of 1″ siding 6 feet long for the two ends
32 ft. of 1″ siding 4 feet long for back of house
24 ft. of 1″ siding 3½ feet long for front of house
16 ft. of 1″ lumber 8 feet long for drop door
90 feet of 1″ lumber for sheathing roof
1 piece 2″x4″x8′ for cross piece to hitch to
4 pieces 2″x4″x8′ for life-saving pig fenders
1 pair 8-inch T-hinges for drop door
1 pair 8-inch strap hinges for door
Nails—No. 20'd. for putting down floor and nailing studding, and 8'd and 10'd for siding and sheathing
1 square three-ply roofing
2 window sash with four glass, each 8″x10″

The Feeding Floor

Where hogs are kept in numbers sufficient to have them rank as an important farm enterprise, a concrete feeding floor often saves time and money. Grain, when fed in quantities to numbers of hogs, may often have a considerable part wasted, and the feeding floor

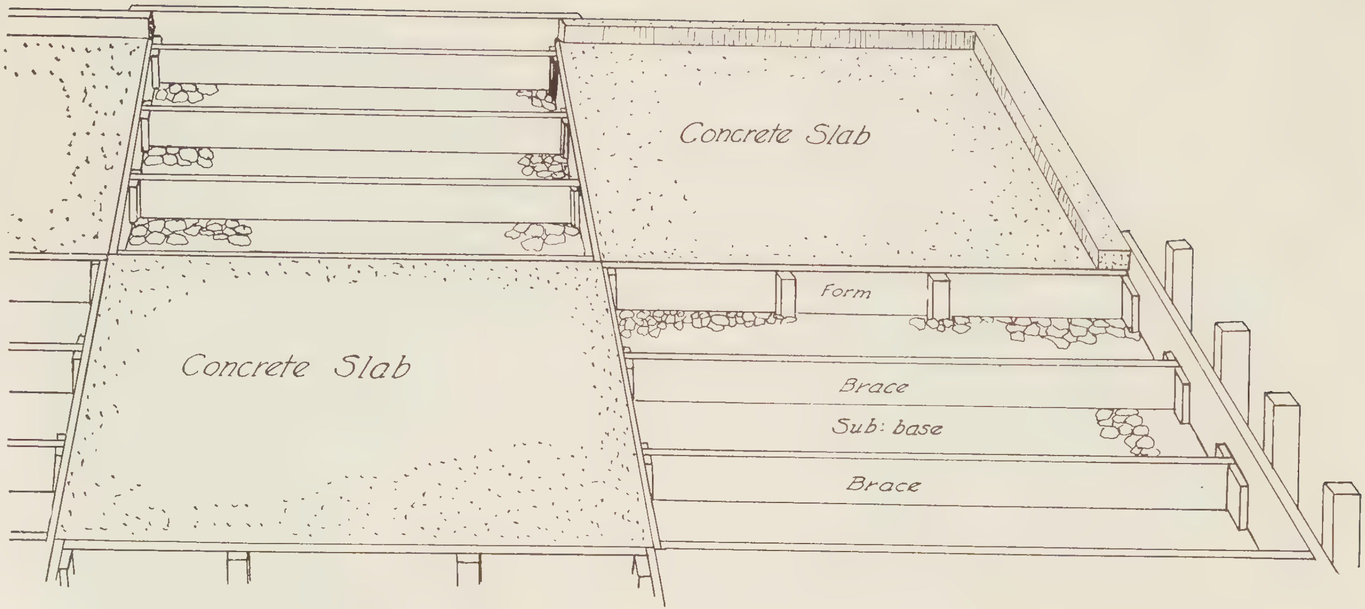


Fig. 26.—Method of constructing concrete feeding floor.

helps to eliminate this. A wooden feeding floor is unsanitary and is a good refuge for rats. It also rots quickly, thereby making it more costly in the long run than concrete.

The feeding floor should have a roughened surface to give good footing and it should also have a slight slope in order to insure proper drainage. It should be constructed in the way a concrete sidewalk is laid, pouring alternate blocks at a time, as shown in Figure 26. These blocks should not be more than 10 by 10 feet, preferably 6 by 6 to 8 by 8 feet. A small feeding floor, however, such as 10 by 16 feet or 12 by 18 feet may be made of one slab of concrete.

A feeding floor should be washed frequently and it may be thoroughly disinfected by spraying with gasoline, and burning.

A Central Hog Plant

For the average West Virginia farm, a community or centralized hog house is too expensive for the number of hogs kept. With a group of farrowing houses and a feeding floor of proper size, a central plant may be effected for convenience in handling the hogs during the winter. This is done by lining the farrowing houses along the edge of the feeding floor and setting up temporary fences on the floor. Such an arrangement is shown in Figure 27. Where houses

A central hog house for a large number of hogs.

Interior of the central house shown on page 42.

are placed on two sides of the feeding floor, an alleyway may be left in the center for convenience.

On a few farms in West Virginia there are enough hogs raised to make a community hog house an economical investment. Since

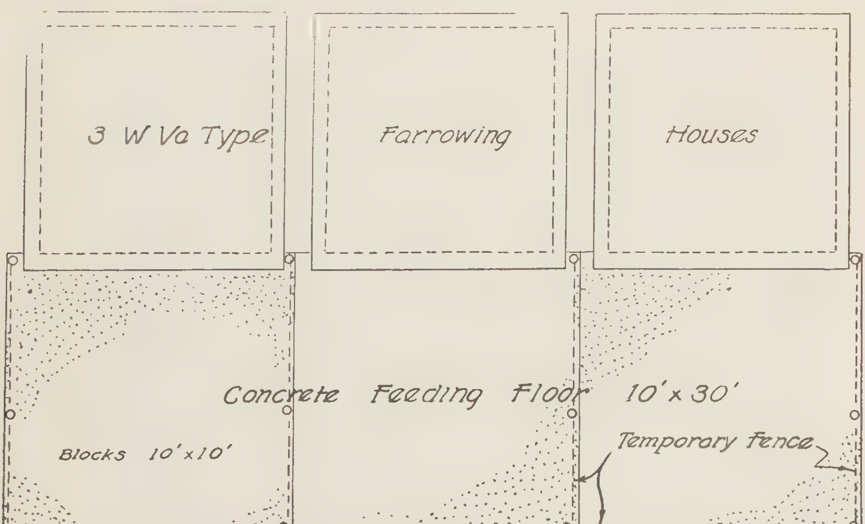


Fig. 27.—Plan showing how colony houses might be arranged about the feeding floor for winter feeding and care.

each such house is an individual problem with varying requirements, a single plan cannot be presented that will meet all conditions. There are a few points to be kept in mind, however.

The hog house should be located farther from the dwelling house than the other farm buildings in order to prevent objectionable odors. In choosing the location, convenience to corn cribs, other buildings, and pastures should also be kept in mind. The slope and drainage of the site, and the location with regard to obtaining the maximum amount of sunlight are additional considerations.

In general, the best arrangement is a double row of pens with feet alley in the center. The average pen is 6 by 8 to 8 by 8 feet, thus making the width of the building 20 or more feet, depending upon the width of the alley. The alley is seldom made more than 4 to 6 feet in width. The length of the building is determined by the capacity desired.

Windows and skylights should be located so as to give an even and adequate distribution of sunlight throughout the pens. Regular metal partitions and gates are the more desirable type since they are durable and sanitary. The illustrations on page 42 and 43 show a central hog plant. Those desiring additional help and information in planning this type of building may obtain it by addressing a request to the College of Agriculture, Morgantown, West Virginia.

A simple but satisfactory forage rack for hogs.

Useful Equipment*

HAY OR FORAGE RACK

In the winter feeding of hogs it is desirable that they be fed amounts of high-quality legume hay. In order to accomplish this with the least expenditure of time and effort, and to prevent waste and soiling of the hay, a forage rack such as is shown in the illustration on page 44 is recommended. This rack is easily constructed. The trough will catch the leaves of the forage as they fall, thus conserving all of the feed.

SELF-FEEDERS

Many experiments have been conducted relative to hand versus self-feeder methods for hogs. The conclusions reached are indicated by the growing use of self-feeders in hog production.

Several types of self-feeders have been designed, the general principle of operation and construction being, however, essentially the same. A very satisfactory type of construction for a self-feeder is shown in Figure 28. This feeder, which was developed by the Purdue Experiment Station, possesses several advantages. Its straight sides and right angles make it easy to construct. The cover over the trough keeps feed in a sanitary condition and helps to prevent waste by keeping out chickens, birds, etc. The feed trough cover may be counterbalanced by using a weight and pulley. This is not necessary, however, as the hogs soon learn to use the feeder. Partitions may be placed in the feeder if desired, thus making it possible to feed different materials separately, such as grain and tankage.

The self-feeder should be visited every day to see that it is working properly; it requires cleaning at times in muddy weather; and it is advisable to locate the feeder near the water supply. The self-feeder method is valuable for fattening hogs, and experiments have shown that the hogs make much more economical gains when feed is before them at all times. The self-feeder, however, should never be regarded as a substitute for watchful supervision by the owner.

PIG NEST

The value and necessity of guard rails or fenders in the farrowing house has been discussed. In addition, however, a pig nest such as is shown in Figure 29 is of real value. This enables the young pigs

*For details of dipping vat construction see Figure 8, page 14. Directions and formulae for dipping hogs may be obtained by writing to West Virginia Agricultural Experiment Station, Morgantown.

to group together for warmth and at the same time eliminates danger of their being crushed by the sow. The nest is most easily constructed in the corner of the building as shown. The supports may be made by 2 by 8 or 2 by 10 inch pieces with cross pieces of one-inch material.

HOG WALLOW

Many farmers still believe that the unsightly and very insanitary mud hole is either essential or inevitable. Neither of these views is correct. The best wallow is a running stream in the pasture. If this is not available a concrete wallow may be constructed at little cost and in such a way as to be readily cleaned. A wallow of this type is shown in Figure 30. A sanitary hog wallow is an aid in controlling parasites.

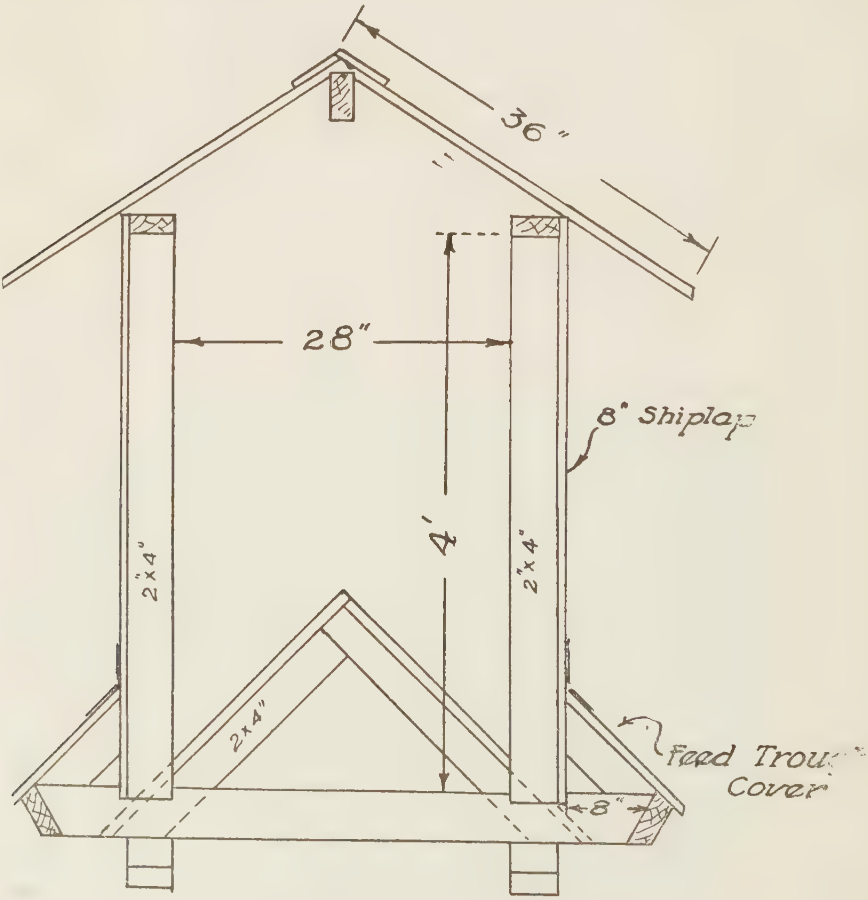


Fig. 28.—One type of self feeder which is simple in construction.

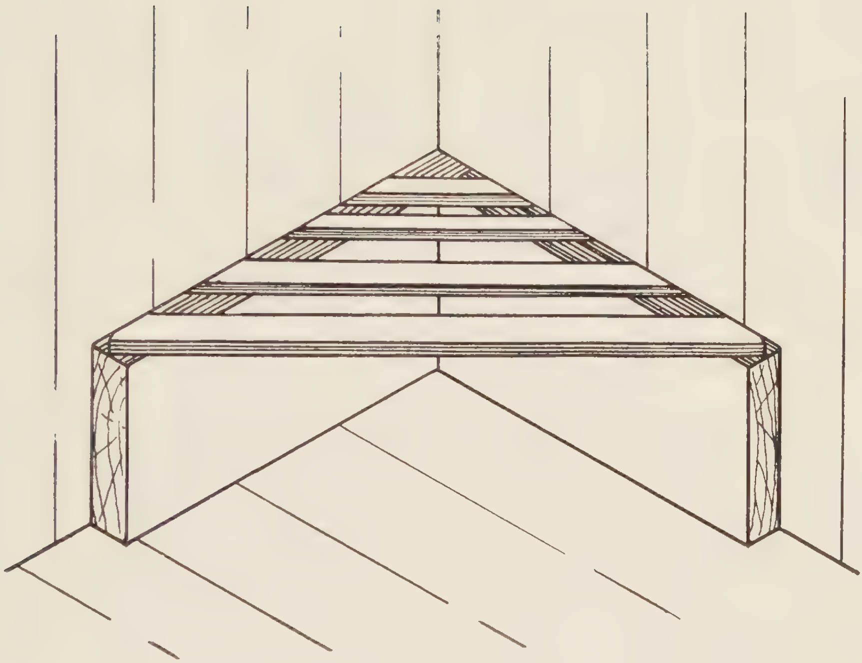


Fig. 29.—Detail of pig nest construction in corner of pen or house.

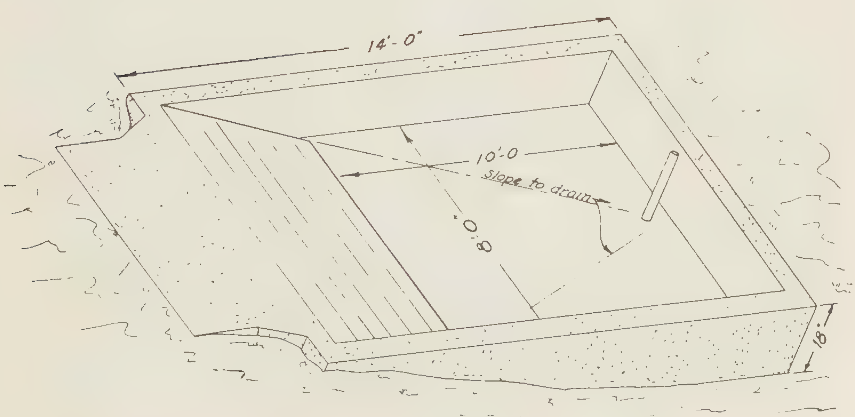


Fig. 30.—Method of constructing a concrete hog wallow.

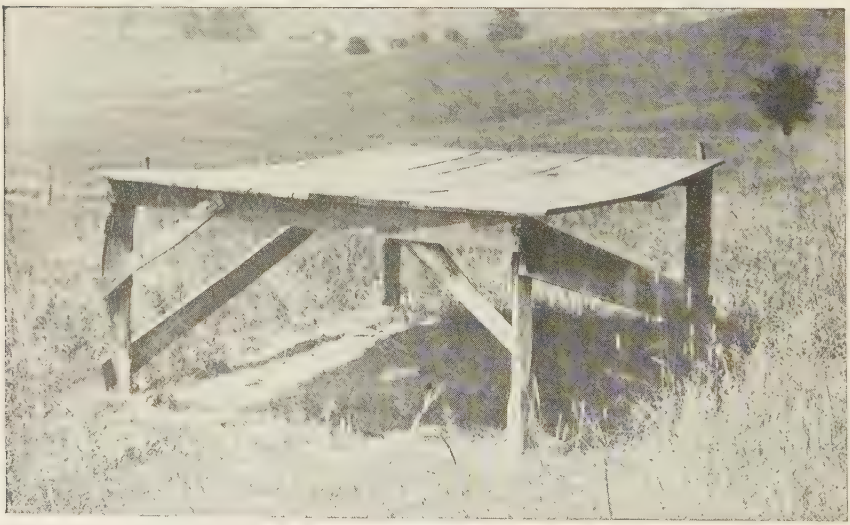
HOG SHADE

Hogs are very readily affected by extremes of heat and cold. During the hot summer months some type of shade is essential. Where the natural shade of trees is not available, some type of artificial shade should be furnished. A type of shade, such as has been tried on the government experimental farm at Beltsville, Maryland, is cheap and effective. This consists of posts set 2 to 3 feet in the ground and projecting above ground about 4 feet. These posts support a framework sufficiently strong to support about two feet of loose straw thrown over the top. With a shade of this type, free circulation of air is not hampered. Boards may be substituted for the straw as shown in the illustration on the bottom of this page.

HOG WATERER

Where there is no spring or stream to supply water for the hogs, some type of automatic waterer adds much to the success of hog production and is much more sanitary than watering in an open trough.

A barrel waterer such as is shown in Figure 31 is satisfactory. The barrel is filled through the large hole in the top, at which time the outlet hole in the bottom must be plugged. The outlet hole should be at least an inch below the top edge of the trough. The trough is 4 inches deep and built so as to fit snugly about the bottom of the



A crude but effective hog shade. Instead of boards poles might be used to support straw or wild hay to a depth of about one and a half to two feet for a cover.

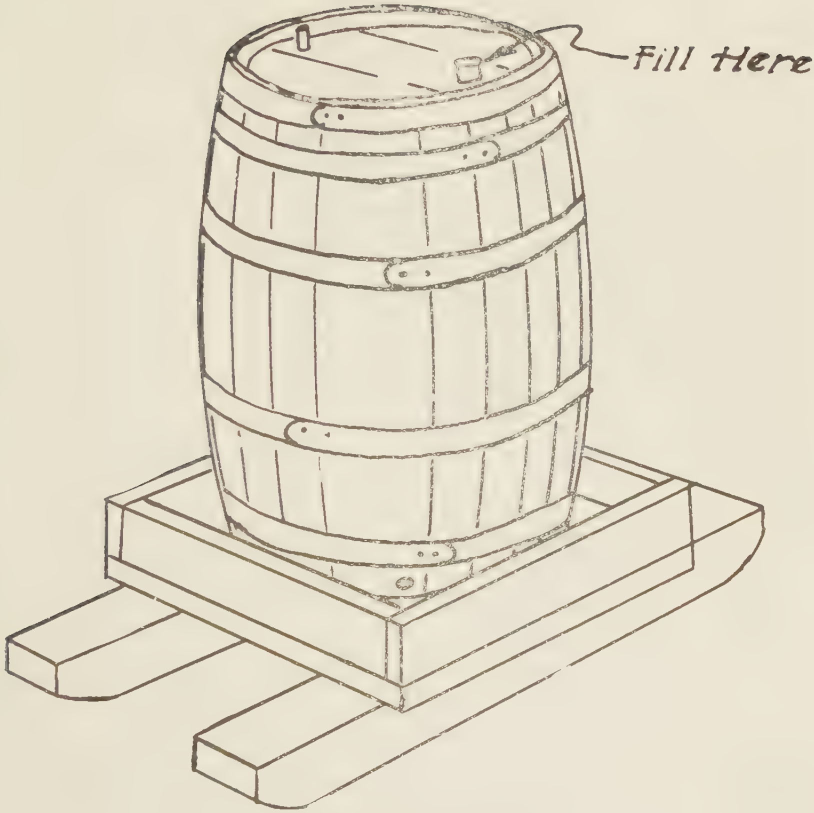


Fig. 31.—A barrel waterer for hogs.

barrel. The runners make it possible to move the waterer from place to place.

HOG OILER

Many commercial types of hog oilers are on the market. One of the cheapest oilers, however, and one which works satisfactorily, is a type which may be quickly constructed at home. This consists of a post set in the ground about which several thicknesses of burlap are tied. The burlap is then saturated with oil.

The only objection to this oiler is that it requires occasional attention in keeping the oil replenished.

Probably the most satisfactory method is to spray occasionally with an ordinary hand spray. The objection to this is that it takes more time, and the average individual is prone to neglect doing it.

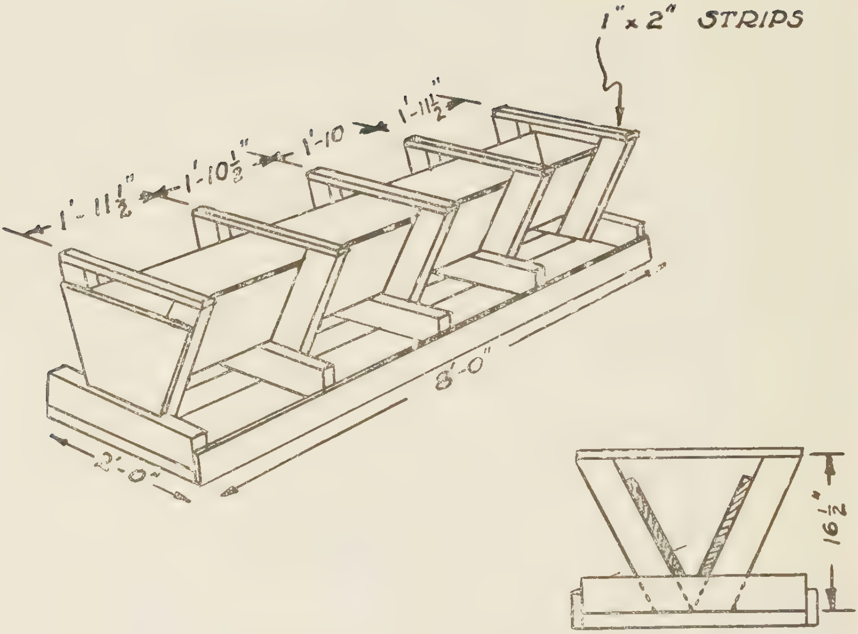


Fig. 32.—A satisfactory type of hog trough. Note the divisions.

FEED TROUGH

No extended discussion is needed on the feed trough. There are all kinds and descriptions of these in use. As in other phases of hog raising, the idea is prevalent that any kind of a trough will do.

As a matter of fact, the best trough is one that will keep the hogs out of it. The ordinary trough in a short time becomes very insanitary unless cleaned regularly. A type of trough used and recommended by the United States Department of Agriculture is shown in Figure 32. Food can be put in this trough without interference, the trough can be cleaned with a hoe, it cannot be overturned easily, and the hogs cannot get their feet in the trough when eating.

Butchering Equipment

Little in the way of elaborate equipment is necessary in handling hogs for butchering. It is surprising, however, how many farmers will expend time and much strenuous labor unnecessarily in the butchering operations.

Hogs are either shot, stunned, or stuck with a knife in killing.

Since the hog has to be bled anyway, the best method of killing, from the standpoint of the quality of the meat, is by sticking. The easiest way to do this is to stick the hog while suspended head downward.

For simplicity, convenience, and low cost, the block and tackle is undoubtedly the first piece of butchering equipment to be recommended. With this attached to a suitable support, the hog may be raised from the ground to be stuck, may be lowered into the water to be scalded, and as easily removed therefrom; and may be suspended for the removing of viscera and final preparation of the carcass for the cutting block. An added advantage of this piece of equipment is that it can be used to lighten innumerable other jobs on the farm. (See Figure 33.)

SCALDING VAT

Many farmers still use a barrel for scalding purposes. This method requires added labor and it is more difficult to obtain as satisfactory results as when a large tank is used. With a barrel, only half of the hog can be scalded at a time, and great difficulty is experienced in keeping the water at the desired temperature (150 degrees) because the large hog in a small amount of water soon lowers the temperature.

One of the best vats for average use is probably a galvanized iron watering trough. This is large enough to permit the scalding to be done properly. A fire may be built under the tank and the desired water temperature thus maintained. There is also enough water to scald the hog at one operation.

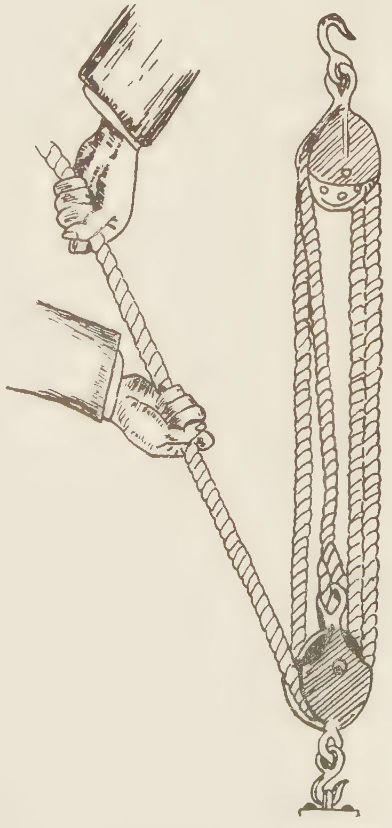


Fig. 33.—A block and tackle forms an important part of the butchering equipment.

THE SMOKE HOUSE

The smoke house may be of different designs, according to differing tastes and financial considerations. If built of wood, it should be far enough removed from the other buildings to avoid any fire hazard. A building such as is shown in Figure 34 works very well and is not unduly expensive. The concrete fire box and the concrete wall carried well above the floor line remove the serious possibility of fire. The fire box on the outside is more convenient. A concrete or wooden vat for the pickling may be placed in the smoke house. For the pickling cure, a barrel makes a good container for the brine.

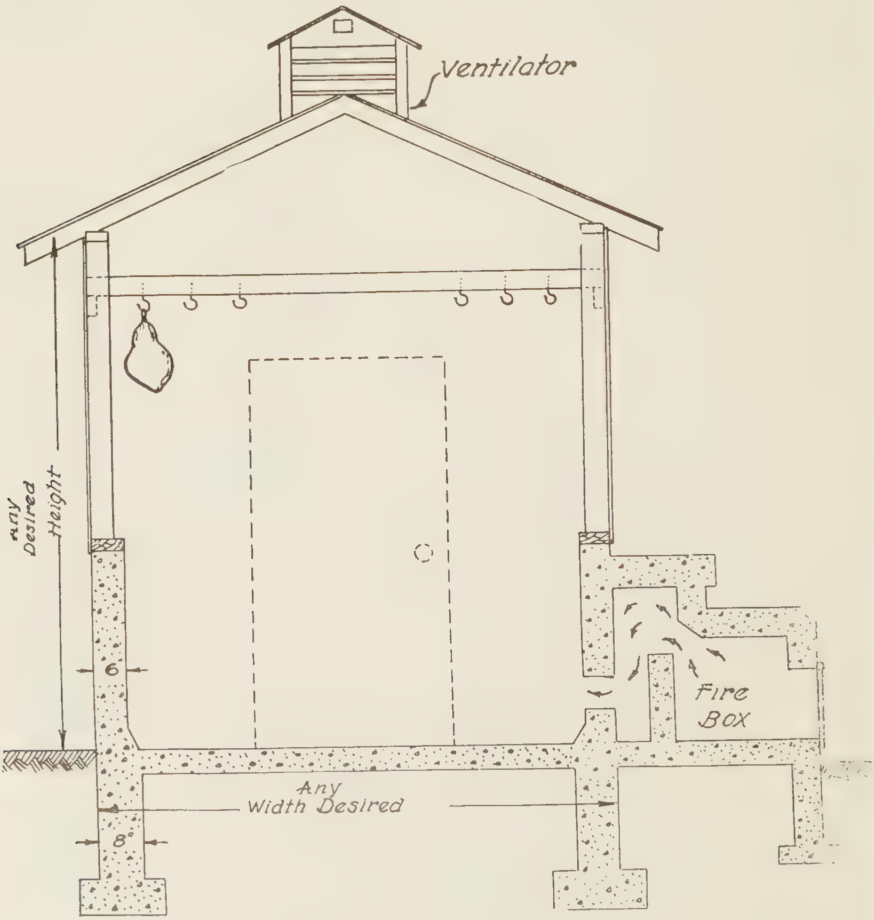


Fig. 34.—General plan for a smoke house.

ESTIMATING FOR BUILDINGS

Excavation

Multiply the length of the excavation by the width and depth in feet and divide by 27. This will give the dirt to be removed in terms of cubic yards.

Concrete

For foundations and floors, the amounts of materials needed may be determined from Table I.

TABLE I.—Quantities of Materials Needed in Concrete Construction*

Mixtures	Materials Required			Quantities from One-sack Batches		Quantities for 1 Cubic Yard of Mixed Material		
	Sacks of Cement	Cubic Feet of Sand	Cubic Feet of Pebbles or Stone	Cubic Feet of Concrete	Cubic Feet of Mortar	Sacks of Cement	Cubic Feet of Sand	Cubic Feet of Pebbles
1:1½	1	1.5	..	1.75	...	15.5	23.2	....
1:2	1	2.0	..	2.1	...	12.8	25.6	....
1:3	1	3.0	..	2.8	...	9.6	28.8	....
1:1½:3	1	1.5	3	....	3.5	7.6	11.4	22.8
1:2:3	1	2.0	3	....	3.9	7.0	14.0	21.0
1:2:4	1	2.0	4	....	4.5	6.0	12.0	24.0
1:2½:4	1	2.5	4	....	4.8	5.6	14.0	22.4
1:2½:5	1	2.5	5	....	5.4	5.0	12.5	25.0
1:3:5	1	3.0	5	....	5.8	4.6	13.8	23.0
1:3:6	1	3.0	6	....	6.4	4.2	12.6	25.2

*Portland Cement Association.

Example: How much cement, sand, and pebbles will be required to build a feeding floor 30 by 24 feet and 5 inches thick?

Multiplying the area (30 by 24) by the thickness in feet ($\frac{5}{12}$ of a foot) gives 300 cubic feet, and dividing this by 27 gives 11$\frac{1}{9}$ cubic yards as the required volume of concrete. A one-course floor should be of 1:2:3 mixture. The table shows that each cubic yard of this mixture requires 7 sacks of cement, 14 cubic feet of sand, and 21 cubic feet of gravel or stone. Multiplying these quantities by the number of cubic yards required (11$\frac{1}{9}$) gives the quantities of material required (eliminating fractions) as 78 sacks of cement, 156 cubic feet of sand, and 233 cubic feet of pebbles or stone. As there are 4 sacks of cement in a barrel, and 27 cubic feet of sand or pebbles in a cubic yard, it will require a little less than 20 barrels of cement, 6 cubic yards of sand, and 9 cubic yards of pebbles or stone.

Sills, Joists, Studding, and Rafters

In figuring the quantity of materials needed for sills, determine the linear measurements of the sills and from this size determine the number of board feet needed. Do the same for all floor joists, studding, and plates. In figuring the studding, no deduction need be made for any wall openings. The total length of the rafters and the number may be determined and figured as the other materials mentioned.

To determine the number of board feet in a piece of timber, multiply the width of the piece in inches by the thickness in inches by the length in feet and divide by 12. For example, a piece 2 inches thick, 12 inches wide, and 12 feet long contains 24 board feet, calculated as follows:

$$\frac{\text{Width } (12'') \times \text{Thickness } (2'') \times \text{Length } (12')}{12} = 24$$

Lumber commonly carried in stock comes in even lengths ranging between ten and twenty feet. Short lengths have a reduced sale value. Lumber for casings and trim is sold by the board foot also, except moldings which are sold by the linear foot.

Flooring, Ceiling, Siding, Sheathing

In estimating the quantity of flooring needed, determine the number of square feet in the floor, including openings as though they were not present, and for three-inch wide flooring add one-half for waste and matching. For wider flooring add from one-fourth to one-fifth instead of one-half. Ceiling for the stable is estimated in the same way as flooring.

To determine the amount of siding needed, calculate the total wall surface in square feet and add one-half, if siding is laid four inches to the weather. If laid 4½ inches or more, add from one-third to one-fourth.

For common sheathing laid horizontally, figure the areas to be covered as though no opening existed, and add one-tenth to the area to allow for waste. If the sheathing is laid diagonally, add one-sixth to the total area.

For tight sheathing laid horizontally, add one-fifth for 6-inch boards, one-seventh for 8-inch boards, and one-ninth for 10-inch boards.. If laid diagonally, add one-fourth for 6-inch boards, one-sixth for 8-inch boards, and one-eighth for 10-inch boards.

Windows and Doors

Windows are ordered by specifying the kind, as single sash or double sash, and by giving the number and size of the glass in each sash.

Doors are ordered in much the same way, by giving the size, thickness, and number of panels desired. The common thickness for doors is 1 ¾ inches and they may be obtained in either A or B quality.

Roofing

When shingles are laid four inches to the weather, 1,000 shingles will cover 100 square feet. Roll roofing contains enough material in each roll to cover 100 square feet. In the case of asphalt shingles, laid four inches to the weather, four bunches will cover 100 square feet.

ACKNOWLEDGMENT:—Acknowledgment is here made of the willing cooperation and valuable suggestions and criticisms given by the several members of the staff of the Animal Husbandry Department, West Virginia University, in the preparation of this circular. Pictures used in cover design were furnished by United States Department of Agriculture.